WASTE-TO-ENERGY: THE NEXT STEP IN THE HIERARCHY AFTER THE 3-Rs

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ABSTRACT

As communities worldwide plan for the management of their solid waste, the issue of what should be the next step in the hierarchy after reduction, reuse and recycling (the 3-Rs) must be addressed. In the 1990's, four North American communities described in this paper made carefully considered decisions to construct properly-sized Waste-to-Energy (WTE) facilities which will work in concert with aggressive 3-R mandates.

The Canadian and US communities' programs described include special features such as battery recycling, and will utilize advanced air pollution control equipment on their WTE facilities. The Canadian example is the Metropolitan Authority project comprised of a joint effort of the City of Dartmouth, the Town of Bedford, the County of Halifax and the City of Halifax, Nova Scotia. The management scheme is 40% 3-Rs, 40% WTE and 20% landfilling. The US examples are the Counties of Lee in Florida, Onondaga in New York, and Montgomery in Maryland. For Lee County, the 3-R mandate is 40% by the start of operation of the WTE facility in 1995. Onondaga County will use its WTE facility to combust only processible non 3-R waste as defined by New York State regulations. Montgomery County's decision is to achieve a 50% rate for the 3-Rs by the year 2000. Its WTE facility is being built with room for a 50% expansion.

In addition, the environmental impact and health risk assessment of the WTE option is compared to the option of raw waste landfilling of the remaining non 3-R waste. The WTE option is shown to have both lower environmental impacts and lower health risk. This is the case primarily because WTE's emit significantly lower quantities of toxic compounds and greenhouse/ozone-producing gases than landfills. Although this paper focuses only on the comparative risks of waste-to-energy and landfills, there are also risks with recycling options, most notably mixed waste composting. Therefore, recycling alternatives should be scrutinized in the same manner as the two options discussed here.

PRESENTATION OF FOUR NORTH AMERICAN COMMUNITIES' INTEGRATED WASTE MANAGEMENT SYSTEMS

Four projects were recently awarded to Ogden Martin Systems (OMS) by communities in North America that currently practice the 3-Rs and have future plans and goals to expand their 3-R programs. However, each of these communities has realized that all 3-R programs have upper limits and that the remaining municipal solid waste is best managed within an integrated system in order to limit landfilling of non 3-R treated waste.

Metropolitan Authority (Dartmouth) N.S. Project

For the City of Dartmouth, the Town of Bedford, the County of Halifax and the City of Halifax, the 3-R program aims at managing forty percent (40%) of the municipal solid waste generated in that region of Nova Scotia. Recovering the energy from another forty percent (40%) serves as the "fourth-R" in the hierarchy, while landfilling will manage the last twenty percent (20%). Figure 1 shows a rendering of the Waste-to-Energy facility; Table 1 lists the pertinent design data.

The facility will be designed to meet the more stringent of Canadian CCME or US EPA air emissions requirements and will utilize an advanced mercury control system and a Selective Noncatalytic Reduction system for control

FIG. 1 METROPOLITAN AUTHORITY WASTE-TO-ENERGY FACILITY

TABLE 1 METROPOLITAN AUTHORITY WASTE-TO-ENERGY FACILITY (Contract Awarded—Implementation, Permitting and Financing in Progress)

GENERAL	
Operator/Owner prior to Acceptance:	Ogden Martin Systems of Nova Scotia, Ltd. 2695 North Sheridan Way Mississauga, Ontario CANADA L5K 2N6 (416) 822-8707
Client/Owner upon Acceptance:	Metropolitan Authority
Construction Date:	February 1994 (Estimated)
Contracted Commercial Operations Date:	April 1996 (Projected)
Guaranteed Construction Price:	$99.6 million Cdn.
Financed Costs:	$117.8 million Cdn.
TECHNICAL INFORMATION	
Site:	± 9.7 hectares in Dartmouth, Nova Scotia
Waste-to-Energy System:	Two, 250 tonnes per day waterwall furnaces with Martin reverse-reciprocating grates and ash handling system
Waste Type:	Municipal, residential and commercial solid waste
Rated Refuse Burning Capacity:	500 tonnes per day
Guaranteed Throughput:	155,000 tonnes per year
Targeted Waste Delivery:	120,000 tonnes per year
Boiler Design:	865 psig/830°F superheater outlet conditions
Air Pollution Control Equipment:	Automatic combustion controls, dry flue gas scrubbers, fabric filter baghouses, NO_x removal system, mercury abatement and continuous emissions monitoring (CEM) system
Energy Generation at Rated Capacity:	17 MW, approximately
Sold To:	Nova Scotia Power Incorporated

of nitrogen oxides. In addition, following Canadian standards, fly ash will be treated separately from bottom ash. The WTE project is currently in the environmental permitting process.

Lee County (Ft. Myers) FL Project

After two years of debate regarding the goals of its 3-R Program, Lee County downsized its planned WTE facility such that by the time the facility begins operation, the 3-R Program must accomplish ten percent (10%) more than is required by the State of Florida's thirty percent (30%) mandate. Thus, the self-imposed forty percent (40%) 3-R Program must be operational in the beginning of 1995 in order to prevent untreated municipal solid waste from being landfilled. This level of 3-Rs includes limited provision for growth of either population or waste generation; however, the facility has been designed for addition of a third unit which would increase its capacity by fifty percent (50%) if required. Figure 2 shows a rendering of the facility, while Table 2 lists salient design data for the facility.

The Lee County Project set a new standard for mercury control as a result of the debate on facility emissions. Not only did Lee County opt to include advanced mercury control, but it also instituted a battery recycling component to its integrated waste management system well in advance of the facility's operation. Construction of the facility began in October, 1992 and is scheduled for completion in Spring, 1995.

Onondaga County (Syracuse) NY Project

The State of New York strictly defines which wastes are subject to the 3-Rs and which qualify to be processed in an WTE facility. Thus, the Onondaga County Resource Recovery Facility will recover energy only from those wastes

FIG. 2 LEE COUNTY, FLORIDA SOLID WASTE RESOURCE RECOVERY FACILITY

TABLE 2 LEE COUNTY SOLID WASTE RESOURCE RECOVERY FACILITY

GENERAL	
Owner/Operator:	Ogden Martin Systems of Lee, Inc. 10500 Buckingham Road Ft. Myers, FL 33905 P. O. Box 9387 Ft. Myers, FL 33902-9387 (813) 337-2200
Client:	Lee County
Construction Start Date:	October 28, 1992
Contracted Commercial Operations Date:	January 27, 1995
Guaranteed Construction Price:	$126 million
Financed Costs:	$179 million
TECHNICAL INFORMATION	
Site:	± 47 acres in Lee County, FL
Waste-to-Energy System:	Two 600 tons-per-day waterwall furnaces with Martin reverse-reciprocating grates and ash handling system
Waste Type:	Municipal, residential and commercial solid waste
Rated Refuse Burning Capacity:	1,200 tons per day
Guaranteed Throughput:	372,300 tons per year
Guaranteed Waste Delivery:	279,225 to 372,300 tons per year
Boiler Design:	865 psig/830°F superheater outlet conditions
Air Pollution Control Equipment:	Automatic Combustion Controls, Dry flue gas scrubbers, fabric filter baghouses, Selective Non-Catalytic NOx Reduction, Mercury Abatement and Continuous Emissions Monitoring (CEM) System
Energy Generation at Rated Capacity:	39.7 MW
Sold To:	Florida Power and Light Company

not slated for the State's 3-R Program. Composting of yard waste eliminates this waste from combustion and is required of Onondaga County by the State's Department of Environmental Conservation. Facility construction began in December, 1992 and is scheduled for completion in Summer, 1995. Figure 3 shows a rendering of the facility and Table 3 lists the design data.

Montgomery County (Rockville) MD Project

After considering and rejecting long distance transport and landfilling of its non 3-R municipal solid waste, Montgomery County decided to fully implement an aggressive integrated waste management system, calling for a fifty percent (50%) 3-R rate by the year 2000 and commencing construction of the Montgomery County Resource Recovery Facility. A unique feature of the system[1] is the transport of municipal solid waste by rail from the transfer station to the WTE facility. The transfer station also plays an important role in the County's 3-R Program. Construction of the Montgomery County facility began in April, 1993 and is scheduled for completion in January, 1996. Figure 4 shows a rendering of the facility and Table 4 presents the design data.

[1] "Comparing Air Emissions from Landfills and WTE Plants," Solid Waste Technologies, March 1994.

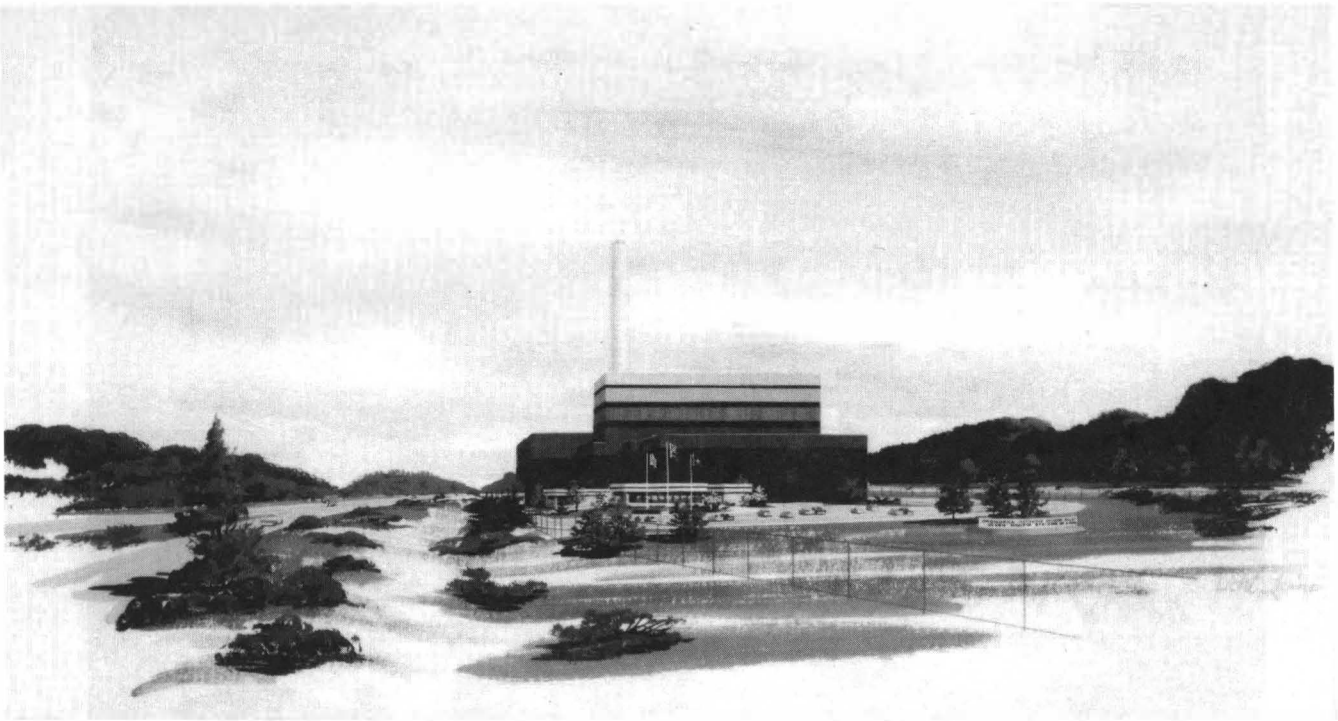

FIG. 3 ONONDAGA COUNTY RESOURCE RECOVERY FACILITY, ONONDAGA COUNTY, NEW YORK

TABLE 3 ONONIDAGA COUNTY RESOURCE RECOVERY FACILITY

GENERAL	
Owner:	Onondaga County Resource Recovery Agency for first 20 years, then Ogden Martin Systems of Onondaga, Limited Partnership
Operated By:	Ogden Martin Systems of Onondaga, Limited Partnership 5801 Rock Cut Road Onondaga, NY 13078 (315) 469-6416
Construction Start Date:	December 1992
Contracted Commercial Operations Date:	May 10, 1995
Guaranteed Construction Price:	$149,000,000 (approx.)
Financed Costs:	$178,050,000 tax exempt revenue bonds
TECHNICAL INFORMATION	
Site:	12 acres in Onondaga County, NY
Waste-to-Energy System:	Three 330 ton per day waterwall furnaces with Martin reverse-reciprocating grates and ash handling system
Waste Type:	Municipal, residential and commercial solid waste
Rated Refuse Burning Capacity:	990 tons per day
Guaranteed Throughput:	310,000 tons per year
Guaranteed Waste Delivery:	295,000 tons per year
Boiler Design:	865 psig/830°F superheater outlet conditions
Air Pollution Control Equipment:	Dry flue gas scrubbers, fabric filter baghouses, Selective Non-Catalytic NOx Reduction and Mercury Control System
Energy Generation at Rated Capacity:	39.5 MW
Sold To:	Niagara Mohawk Power Corporation

PRESENTATION OF THE ENVIRONMENTAL AND HEALTH RISK COMPARISON BETWEEN WASTE-TO-ENERGY FACILITIES VERSUS LANDFILLS

To effectively evaluate the most appropriate waste management technique for the remaining waste after application of the 3-Rs, the environmental impacts and health risks associated with each method must be compared on an equivalent basis. The analysis presented here compares direct combustion of solid waste for energy recovery with the landfilling of waste, followed by the capture of a portion of the resulting gaseous emissions and subsequent combustion of the gas for energy recovery. The comparison examines the following crucial environmental and public health considerations: 1) Energy Recovery, 2) Equivalent Greenhouse Gas Emissions, 3) Emission Factors of Important Air Pollutants, 4) Total Non-Methane Hydrocarbon Emissions, 5) Total Hazardous Air Pollutant Emissions, 6) Health Risks Associated with Dioxin Emissions and 7) Health Risks Associated with Benzene and Vinyl Chloride Emissions. Data on these seven aspects are derived from the combustion characteristics and emissions of a hypothetical 1500 ton per day WTE facility and from the landfill gas generation rate, combustion characteristics and associated emissions from a similarly located 1500 ton per day landfill.[2]

[2]The methodology employed in these analyses are described in a paper by K. Jones, 1994.

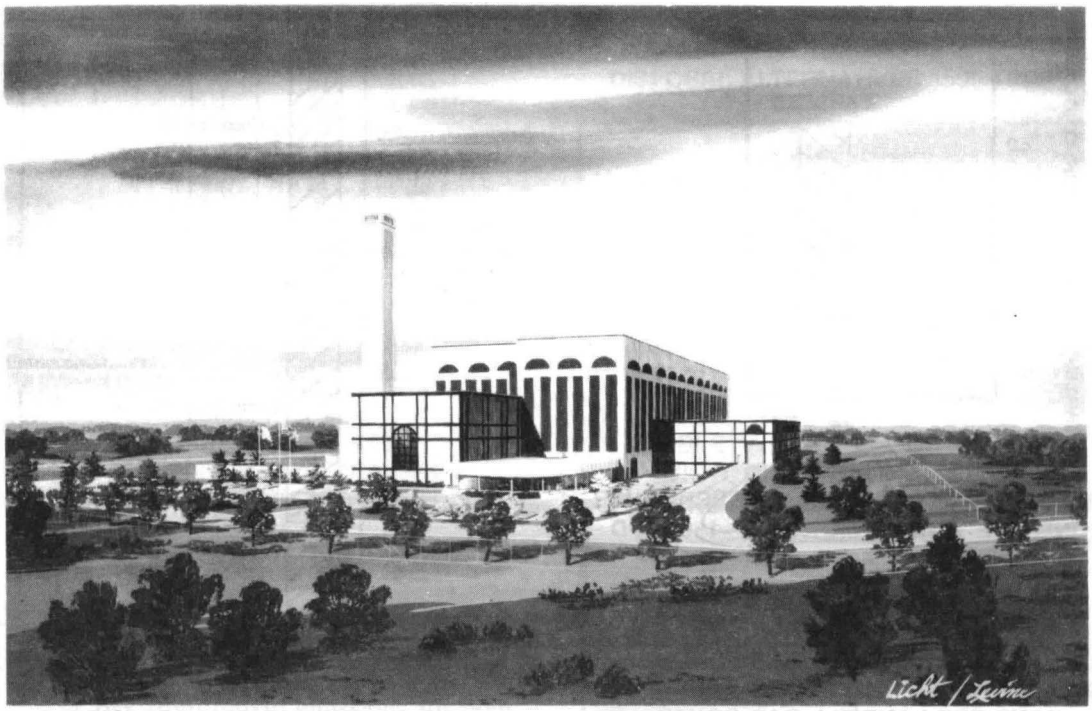

FIG. 4 MONTGOMERY COUNTY RESOURCE RECOVERY PROJECT, MONTGOMERY COUNTY, MARYLAND

TABLE 4 MONTGOMERY COUNTY SOLID WASTE RESOURCE RECOVERY FACILITY

GENERAL	
Owner:	Northeast Maryland Waste Disposal Authority
Operator:	Ogden Martin Systems of Montgomery, Inc. 40 Lane Road Fairfield, NJ 07007
Construction Data:	April 6, 1993
Contracted Commercial Operations Data:	January 12, 1996
Estimated Construction Price:	$275 million
TECHNICAL INFORMATION	
Site:	34.9 acres in Dickerson, MD
Waste-to-Energy System:	Three, 600 ton-per-day waterwall furnaces with Martin reverse-reciprocating grates and ash handling system
Waste Type:	Municipal, residential and commercial solid waste
Rated Refuse Burning Capacity:	1,800 tons per day
Guaranteed Throughput:	558,450 tons per year
Boiler Design:	865 psig/830°F superheater outlet conditions
Air Pollution Control Equipment:	Dry flue gas scrubbers, fabric filter baghouses, lime injection system, nitrogen oxide controls and mercury control system
Net Energy Generation at Rated Capacity:	48 MW
Sold To:	Potomac Electric Power Company (PEPCO)
Special Feature:	Waste is transported from the Transfer Station in Derwood to the Facility Site by railroad.

COMPARISON OF ENERGY RECOVERY

Using the landfill gas capture and generation rate proposed by the US EPA and typical Ogden Martin Systems (OMS) Waste-to-Energy combustion calculations, the energy recovery from direct combustion of non 3-R waste is almost three times that gained from burying waste and capturing the gas produced by the slow biodegradation typical of landfilled waste and burned in a gas-to-energy plant. Figure 5 presents this comparison of the first aspect.

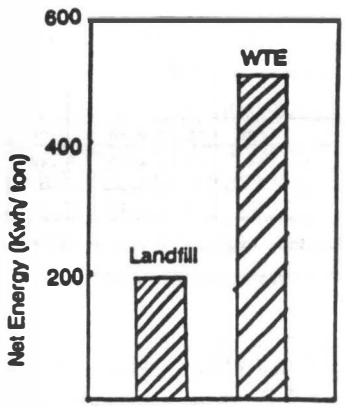

FIG. 5 COMPARISON OF ENERGY RECOVERY RATES WTE VERSUS LANDFILL—1500 TPD

COMPARISON OF EQUIVALENT GREENHOUSE GAS EMISSIONS

Considering the methane (CH4) and carbon dioxide (CO2) emissions from both the direct combustion of non 3-R waste and the fugitive release and combustion of landfill gas produced after burying non 3-R waste, and con-

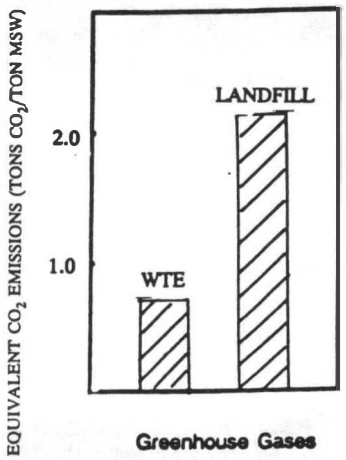

FIG. 6 COMPARISON OF EQUIVALENT GREENHOUSE GAS EMISSIONS WTE VERSUS LANDFILL—1500 TPD

TABLE 5 COMPARISON OF EMISSIONS FACTORS FOR CO, NMNOC, NO_x AND DIOXINS/FURANS FOR LANDFILL GAS CONTROL OPTIONS VERSUS WTE TECHNOLOGY

		EMISSIONS FACTORS ($lb/10^6$ BTU)		
DISPOSAL OPTION	CO	NMOC	NO_x	DIOXIN/FURAN
WTE	.022	1.10×10^{-3}	.24	$2.9 \times 10^{-9(2)}$
Landfill Gas Control By:				
Flare	.088	$11.23 \times 10^{-3(1)}$	.044	11.67×10^{-9}
Internal Combustion Engine	.51	11.23×10^{-3}	.42	5.52×10^{-9}
Gas Turbine	.088	11.23×10^{-3}	.22	ND

(1) NSPS = 98% reduction, excludes fugitive emissions.

(2) Equivalent to 3.0 ng/m^3 total PCDD/PCDF

verting to equivalent CO2 emissions, it is evident that the landfilling of non 3-R waste generates over two times the equivalent greenhouse gas emissions of direct combustion. Figure 6 details the rates discussed above.

EMISSION FACTORS OF IMPORTANT AIR POLLUTANTS

Emission factor comparisons allow critical review of different sources on the same input basis. The three predominant methods of landfill gas combustion, i.e., flares, internal combustion engines (ICE) and gas turbines, can thus be compared to direct waste combustion on a common heat input basis for emission of carbon monoxide (CO), non-methane hydrocarbons, nitrogen oxides (NOx) and dioxins (PCDDs/PCDFs). Table 5 shows that emission factors of direct waste combustion are lower.

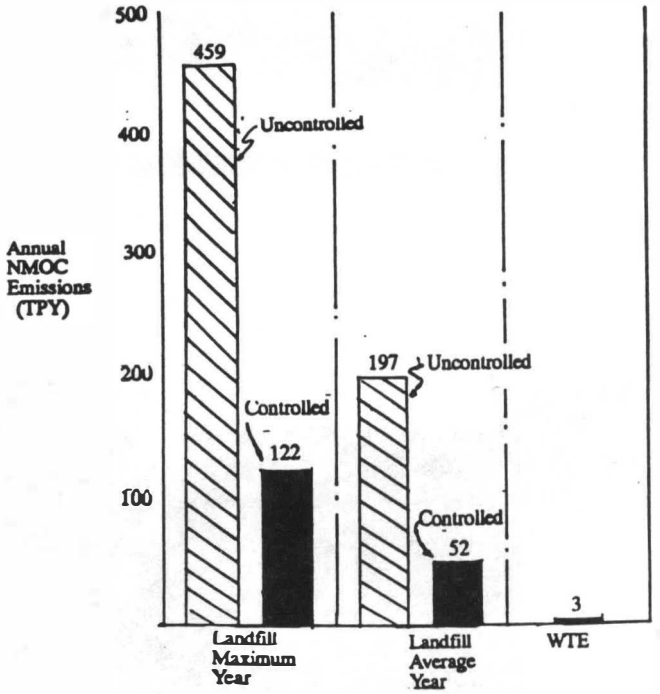

FIG. 7 COMPARISON OF LANDFILL VERSUS WTE NON-METHANE ORGANIC CARBON (NMOC) EMISSIONS 1500 TPD FACILITIES

TOTAL NON-METHANE HYDROCARBON EMISSIONS

When fugitive emissions and combustion emissions of captured landfill gas are compared to the emissions of non-methane hydrocarbons from the direct combustion of non 3-R waste, the extremely small amount from direct combustion is far overshadowed by the levels being emitted by the landfill. Figure 7 shows this dramatic difference, particularly considering that twenty-five percent (25%) of the landfill gas escapes uncontrolled.

TOTAL HAZARDOUS AIR POLLUTANT EMISSIONS

The US EPA has identified and listed 189 Hazardous Air Pollutants of concern; of those 189, thirty (30) have been identified by the US EPA as being contained in landfill gas emissions. Seven of the more toxic of these 30 hazardous air pollutants are estimated to be emitted from uncontrolled landfills at levels above US EPA guidelines. The emission levels of these seven more toxic hazardous air pollutants are shown in Figure 8.

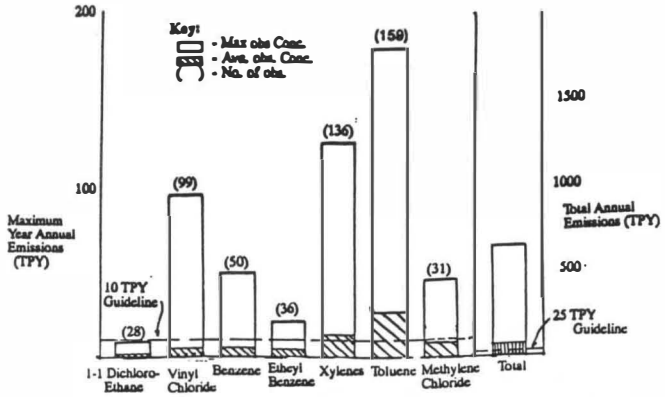

FIG. 8 ESTIMATED UNCONTROLLED EMISSIONS OF SEVEN (7) HAZARDOUS AIR POLLUTANTS (HAPS) FROM A 1500 TPD LANDFILL

HEALTH RISKS ASSOCIATED WITH DIOXIN EMISSIONS

While the cancer risk from dioxin emissions for both direct combustion and combustion of landfill gas is lower than North American governmental criteria, a multi-pathway health risk assessment shows that direct combustion provides less exposure/risk than combustion of landfill gas by factors of 6 to 60. Table 6 presents actual risk levels and relative risks.

HEALTH RISKS ASSOCIATED BENZENE AND VINYL CHLORIDE EMISSIONS

For these two known human carcinogens, benzene and vinyl chloride, the inhalation cancer risk evaluation shows the same trend as dioxin, except that the factors for direct combustion are lower by 10 to 20,000. Table 7 gives comparative risk data as well as actual risk levels.

SUMMARY

As communities across North America plan and implement their integrated waste management systems emphasizing the 3-Rs, the "Fourth-R", i.e. resource recovery (Waste-to-Energy), should be favored over landfilling for remaining non 3-R waste because:

TABLE 6 COMPARISON OF MULTIPATHWAY DIOXIN/FURAN CANCER RISKS FOR THREE MSW DISPOSAL ALTERNATIVES 1500 TPD FACILITIES

DISPOSAL METHOD	MULTIPATHWAY CANCER RISK[1] (chances/million)	RELATIVE RISK AMONG ALTERNATIVES
WTE	.07	1
Composting	11.0	157
Landfill With:		
Flare	.45	6.4
ICE	4.2	60

[1] Multipath-way to inhalation risk ratio of 35:1 from Montgomery Co. MD R/A except for the composting case which was based on the Dakota Co. MN R/A.

TABLE 7 COMPARISON OF BENZENE AND VINYL CHLORIDE CANCER RISKS—WTE VERSUS LANDFILL 1500 TPD FACILITIES

	BENZENE		VINYL CHLORIDE	
DISPOSAL OPTION	RISK (chances/million)	RATIO (option/WTE)	RISK (chances/million)	RATIO (option/WTE)
WTE	.00023	1	ND[1]	NC[2]
Landfill Fugitive Emissions	4.8	20,870	13.6	NC
Landfill Gas Control By:				
Flare	.0022	9.6	.09	NC
ICE	3.4	14,780	.51	NC

[1] Not detected (ND) in emissions test.

[2] Not calculated (NC).

(*1*) When new landfill and Waste-to-Energy facility models of equal capacity are compared from a risk perspective, the landfill can pose far greater health risks than the Waste-to-Energy option.

(2) New landfills may pose air toxic risks that exceed acceptable North American governmental guidelines and/or regulations.

(*3*) New landfills located in areas of ozone nonattainment may fail to meet governmental requirements for control of ozone precursors.

(*4*) Landfills will emit more greenhouse gases and recover less energy than the Waste-to-Energy alternative.

Communities must realize, that while this paper focuses only on the comparative risks of waste-to-energy and landfills, there are also risks associated with recycling options, and most notably with mixed waste composting. Recycling alternatives must be scrutinized in the same manner as the two options discussed here.