WASTE TO ENERGY: A POSSIBILITY FOR PUERTO RICO

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Columbia University
School of International and Public Affairs

Michael Carim, Whitney Blake, Alex Amerman, Billy Gridley, Monica Kurpiewski, Sung Ah Lee, Safet Marke, Nina Kishore, Adam Raphaely, Allison Diana Reilly
Faculty Advisor: Dr. Steven Cohen

Table of Contents

EXECUTIVE SUMMARY

Puerto Rico is reexamining its options for municipal solid waste (MSW) management. Currently, the island relies on 32 landfills for the vast majority of waste disposal. The necessary pollution controls are installed in only five of these landfills. The remainder face eventual closure because they do not employ systems to capture leachate and methane emissions. Compounding this problem is the island's size, approximately 130 square miles, which may render landfilling an unsustainable MSW management strategy. Land scarcity and the costs of compliance with environmental statutes will make the siting of new landfills in Puerto Rico increasingly expensive in the future.

Waste-to-Energy (WTE) plants may provide a feasible alternative to landfills in Puerto Rico. WTE plants burn waste and use the heat from combustion to generate electricity, reducing the total volume of waste by 90%. This technology is widely utilized in developed countries, especially on islands and densely populated areas where land scarcity discourages landfilling. WTE may also be preferable for environmental reasons. WTE technology employs a variety of pollution control devices to minimize atmospheric emissions from combustion. Levels of dioxin, heavy metals, and other regulated contaminants emitted from WTE facilities are well within EPA limits.

Despite great improvements in emissions control and a drastic reduction in dioxin levels, some members of the public remain concerned about the potential environmental and health effects of WTE. Historically, public opposition in response to these concerns has constrained the ability to site WTE facilities. Public opposition may be reduced through public education campaigns and community involvement in the siting process.

Combustion and gasification are the two primary WTE technologies in use today. The technological choice will depend on the size and composition of Puerto Rico's waste stream. There will also be options to consider regarding emissions controls and recycling in conjunction with WTE. Installation of a WTE facility should be associated with an improved recycling program because the WTE process is more efficient when recyclable material is removed.

An economic model is introduced to compare the costs of installing new landfills and WTE facilities. The model employs a bottom-up analysis of economic factors, such as land and construction costs, tipping fees and revenue from electricity and recovered materials in order to estimate the tipping fees at a WTE facility in Puerto Rico. Landfill tipping fees are estimated to be $45/ton to $60/ton; WTE tipping fees are estimated at $54/ton to $62/ton. Various financing options exist, but, in general, WTE facilities are financed with a mixture of public debt and private equity. It is also possible that an existing private entity or a new entity, with public sector involvement and sponsorship, could finance a WTE facility in Puerto Rico.

It is important to address public concerns that may hinder the ability to site a WTE facility. Past experiences in other countries may provide useful suggestions for successful siting of a WTE facility in Puerto Rico. Case studies from Florida, Bermuda and Hawaii provide more detailed views of the technological, economic and political aspects of siting WTE facilities.

INTRODUCTION

Puerto Rico is examining new ways to dispose of municipal solid waste (MSW). Waste is currently placed in open dumps with minimal environmental controls, which has lead to the release of hazardous materials into the soil, air and water. Puerto Rico's government is aware of the need to modify its waste disposal practices. To date, half of Puerto Rico's 68 landfills have been closed[1] and only four of the remaining landfills could be retrofitted with environmental controls. Even with retrofits, their combined capacity could handle Puerto Rico's waste for no more than ten years[2].

In 2004, $620 million was allocated to the Solid Waste Authority over ten years for the purpose of funding MSW management in Puerto Rico.[3] A new solid waste plan for Puerto Rico will be developed that includes an updated recycling program, remediation of leaking landfills and, potentially, waste-to-energy (WTE) facilities.[4]

Any MSW plan created for Puerto Rico will need to incorporate multiple strategies for waste management. Creative and environmentally friendly solutions beyond landfilling should be considered because Puerto Rico has limited land and a steadily growing population. Waste minimization, recycling, landfilling, incineration and energy recovery should be thoroughly examined to develop a comprehensive, integrated MSW strategy.

Section I of this report examines Puerto Rico's existing landfills and compares them to those that meet necessary environmental regulations. It also establishes the need to reexamine how waste is managed in Puerto Rico. Limited land on the island may make other waste management strategies more attractive. This section also discusses the need for a new MSW management plan in Puerto Rico. Some landfills must be closed and may be replaced, in part, with compliant landfills, increased recycling, the export of waste off the island, and WTE facilities. The decision of which strategies to integrate into a municipal solid waste plan will be dictated by the comparative environmental and economic costs, Puerto Rico's waste stream and land scarcity.

Section II discusses how WTE could be used as one component of an integrated waste management program in Puerto Rico. This section presents the basic environmental benefits of WTE for Puerto Rico. It also examines the history of WTE in the US to establish the technological and economic factors that might affect the siting of a WTE facility in Puerto Rico.

Section III presents the need to address public opposition to WTE. Historically, in many instances, community disapproval has inhibited the siting of WTE facilities. Public involvement may improve the feasibility of using WTE in Puerto Rico.

Section IV describes the two types of WTE technology that might be considered for use in Puerto Rico: combustion and gasification. This section also addresses the technological concerns about WTE raised in Sections II and III.

Section V discusses the economic factors that should be considered when siting a WTE facility. We created a model to analyze interacting factors, such as plant and construction cost, facility capacity, tipping fees, other WTE revenue sources and financing rates. Finally, financing options that Puerto Rico might consider are outlined in this section.

Section VI provides suggestions for community involvement, as a response to the public concerns outlined in Section III. A community involvement plan might include meetings for public education and dialogue and a citizen advisory board. This section also examines how other governments have dealt with public opposition and successfully sited WTE facilities.

Section VII summarizes the conclusions and findings of this report and, suggests next steps that may be taken by local officials to further examine WTE's role in Puerto Rico.

Finally, three case studies are presented to illustrate how other locations have successfully sited WTE facilities. The Broward County Waste and Recycing Center in Fort Lauderdale, Florida, Tynes Bay Incinerator in Bermuda and the Covanta Honolulu Waste Recovery Venture in Hawaii, provide background information about siting WTE facilities in locations similar to Puerto Rico.

I. THE NEED FOR A NEW WASTE MANAGEMENT PLAN

Puerto Rico's Landfills

27 of Puerto Rico's 32 dumps fail to comply with environmental regulations established by the United States Environmental Protection Agency (USEPA) in the Resource Conservation and Recovery Act (RCRA). [5] Subtitle D of the Act outlines the environmental controls necessary to preserve public health and to protect the environment from pollutants in the waste within a landfill.[6]

Because Puerto Rico's landfills do not employ the necessary pollution controls,[7] they pose a serious threat to the environment and to public health.[8] As waste decomposes, hazardous material it might contain combines with rainwater, to form leachate, which enters and contaminates soil, surface water and groundwater. In addition to leachates, landfills also emit gaseous methane and carbon dioxide into the atmosphere. These gases are created when organic materials in the waste decompose.

Compliant landfills or alternative forms of waste management will need to be adopted to minimize the release of pollutants from Puerto Rico's waste stream. The island's waste management decisions will be influenced by the size of its waste stream and the feasibility of siting compliant landfills due to land scarcity.

Puerto Rico's Waste Stream

Puerto Rico produces 3,598,972 tons annually of MSW, the equivalent of 5.18lbs pounds per day per person.[9] The volume of MSW generated is expected to increase as population growth proceeds at 0.4% per year.[10] Exhibit 1 represents the current compostion of Puerto Rico's municipal solid waste. Appendix A outlines the necessity and a process for conducting regular, uniform waste inventorys.

Average Waste Stream	
Plastic	*10.4%*
Paper/Cardboard	*19.4%*
Metals	*10.4%*
Yard Waste	*20.5%*
Organic	*13.1%*
Construction Debris	*17.0%*
Glass	*2.4%*
Household Hazardous Waste	*0.5%*
Other	*6.3%*

Exhibit 1: Composition of Puerto Rico's municipal solid waste stream[11]

The current recycling rate in Puerto Rico ranges from 0% to 15%, depending on the region.[12] Many more materials such as glass, plastic, paper, metal, ferrous and non-ferrous, and organic matter, could potentially be recycled. These materials comprise 42.6% of the waste stream, but currently there is no indication that a market would develop that would make recycling all of these materials economically feasible. There is, however, an expressed interest in a program designed to increase the recycling rate as part of an integrated waste management plan in Puerto Rico.

Puerto Rico's waste will most likely be handled domestically for financial reasons. Under US law there is no prohibition against the import or export of waste.[13] Puerto Rico has exported limited amounts of

MSW in the past. For example, in 1998, 84,270 tons of MSW from Puerto Rico, 2.5% of all MSW produced that year, were accepted in Virginia.[14] The economic feasibility of exporting large quantities of MSW from Puerto Rico is uncertain. The volatility of shipping costs alone would deter pursuit of export as a solution in the absence of long-term transport contracts.[15] Puerto Rico would also have to pay standard tipping fees to the facility receiving waste exports.

RCRA Subtitle D Landfills

RCRA Subtitle D requires the installation of controls on landfills to prevent pollutants from exiting and to monitor the environmental impact of the landfill. Subtitle D mandates the use of liners, leachate collection systems and groundwater monitoring systems.[16] Liners provide a physical barrier on the bottom and sides of a landfill to contain toxic wastes and leachate. Leachate collection systems remove contaminated liquids from the landfill for treatment.[17] The gaseous collection system captures gases from the landfill that would otherwise be released into the atmosphere. These gases can either be flared off or combusted to create electricity.[18] Groundwater monitoring systems test nearby groundwater for contamination to ensure that control mechanisms are working properly.[19]

The cost of building compliant landfills is expected to be high in Puerto Rico because land is scarce[20]. Trends in development reveal that low-density urban sprawl is occurring, which increases pressure on land use.[21] The inherent geographic constraints of small islands place a premium on land use planning in waste management policy. The total area of Puerto Rico is 8,870 square kilometers (3424 square miles),[22] of which 13% is developed.[23] Planners must account not only for the island's small size, but also that many areas of the remaining 87% may not be available for landfilling. For example, about 28% of the island, primarily in the northwest region, is karst topography and unfit for landfilling.[24]

The siting of landfills could also be precluded by land use regulations, development trends, or the unavailability of land close to highly populated areas or roadways. Most of the interior topography is rugged and mountainous, meaning the majority of future development, and hence waste generation, will occur near coastal regions where land is scarcer. Given these limitations, it is unlikely that landfills will be the exclusive component of a sustainable waste management policy. The combination of land scarcity and the need for large amounts of land on which to site a landfill place landfilling at a competitive disadvantage relative to alternative waste management practices. The projected economic cost of installing compliant landfills in Puerto Rico will be discussed in Section V.

Because compliant landfills may still emit some pollutants, the creation of new landfills in Puerto Rico is not without environmental costs. Landfills are the largest producer of methane in the United States, and as a greenhouse gas methane is 21 times more potent than carbon dioxide.[25] Other gaseous emission, including volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO_2), trichloroethylene, carbon tetrachloride, vinyl chloride, benzene, chloroform, and methylene chloride, all of which may impact local environmental quality significantly.[26] A study by Miranda and Hale monetizes the environmental costs of landfill emissions, with and without gas flaring. The authors compile cost data for landfill pollutants from prior studies that include direct estimates of environmental and human health effects, the cost of pollution abatement technology, and the contingent valuation of avoiding impacts to public health and the environment. Without gas flaring, the total environmental cost is estimated between \$13.8 and \$73.4 per ton MSW. With flares installed, the environmental cost from leachate and air emissions is estimated between \$7.50 and \$22.30 per ton of MSW.[27]

II. WTE AS PART OF A NEW WASTE MANAGEMENT PLAN

WTE facilities are an alternative to new landfills in Puerto Rico. WTE is the incineration of municipal solid waste to produce electrical energy. As of 2003, more than 600 WTE plants had been constructed around the globe.[28] These plants process roughly 130 million metric tons of municipal solid waste annually.[29] In the US, there are 88 active WTE plants that process 950 tons of garbage per day, or 8 % of total domestic MSW.[30] These facilities provide electricity for 2.3 million American homes, accounting for 20% of all renewable energy produced in the United States.[31] In Europe, there are over 400 facilities that treat 50 million tons of waste each year. European WTE facilities generate 27 million MWh of electricity from WTE, enough energy to supply electricity to 27 million homes. This is equivalent to providing electricity to the entire population of the Netherlands, Denmark and Finland.[32] In Japan, there are over 100 WTE facilities that process 70-80% of Japan's MSW [33].

Country	Recycled/composted and other (percent of total)	Landfill (percent of total)	Incineration (percent of total)	Waste per capita (kg)
Netherlands	65	3	32	624
Austria	59	31	10	627
Germany	58	20	22	600
Belgium	52	13	35	469
Sweden	41	14	45	464
Denmark	41	5	54	696
Luxembourg	36	23	41	668
Spain	35	59	6	662
Ireland	31	69	0	869
Italy	29	62	9	538
Finland	26	63	9	455
France	28	38	34	567
UK	18	74	8	600
Greece	8	92	0	433
Portugal	3	75	22	43

Exhibit 2. Municipal waste management practices in the European Union, 2004[34]

Country	**Number of WTE plants**	**Treated waste (million tonnes)**
Netherlands	12	5.18
Austria	5	0.88
Germany	58	13.18
Belgium	17	1.64
Sweden	28	3.13
Denmark	31	3.28
Luxembourg	1	0.12
Spain	11	1.86
Finland	1	0.15
Italy	49	3.47

Hungry	1	0.19
France	123	11.25
UK	15	3.17
Norway	21	0.79
Portugal	3	1
Switzerland	29	2.97
Czech Republic	3	0.4
Poland	1	0.04

Exhibit 3. Waste-to-Energy plants in Europe and volume of waste treated, 2003.[35]

Although, WTE technology is used in a wide range of locations, it is still most common in densely populated and/or geographically isolated areas, such as islands, where landfill costs are high. WTE plants are especially common in the US, Western Europe, and Asia.[36] Examples of islands with WTE plants include Japan, Hawaii, Bermuda, Ireland, and the Canary Islands.

WTE facilities may provide an environmentally beneficial alternative to traditional waste disposal methods. The combustion of municipal solid waste in WTE facilities prevents the possible aqueous and gaseous pollution associated with landfilling and provides a source of clean, renewable energy. WTE plants also reduce the land needed for landfilling. Landfills hold 10 tons of waste per square meter.[37] Puerto Rico produces over 3 million tons of waste per year, which equates to more than 300,000 square meters of land consumed per year. By contrast, a WTE facility requires a single investment of 20,000 to 100,000 square meters,[38] and the ash byproduct is only 10% of the volume of the original waste stream.[39] Ash may be landfilled or sold for uses such as construction fill.

History of WTE in the US

The WTE industry developed in the late 1970s in response to higher energy prices, tighter environmental standards and increased costs of traditional landfill waste disposal. Interest grew due to the interaction of several factors, including public perception of an impending landfill crisis, tax breaks and power purchase agreements for potential investors, and the search for new energy sources as a result of growing opposition to nuclear power.[40] Exhibit 4 shows the growth and decline in the total number of WTE facilities over the last two decades.

According to Berenyi, the industry's decline in the 1990s primarily was due to five causes:

1. The Supreme Court *C & A Carbone v. Town of Clarkston, New York* struck down flow control. Plants were forced to compete for waste and could no longer rely on long-term contracts for the bulk of their waste supply.
2. The Supreme Court *City of Chicago et al. v. Environmental Defense, et al.* mandated testing of ash for toxicity and its proper disposal, which necessitated increased industry costs.
3. Landfill space continued to be available relatively cheaply.
4. Amendments to the Federal Clean Air Act 1990 mandated more intensive and expensive air pollution control systems.
5. The deregulation of power utilities opened the electric industry to competitive power generation, which resulted in declining electricity prices.[1]

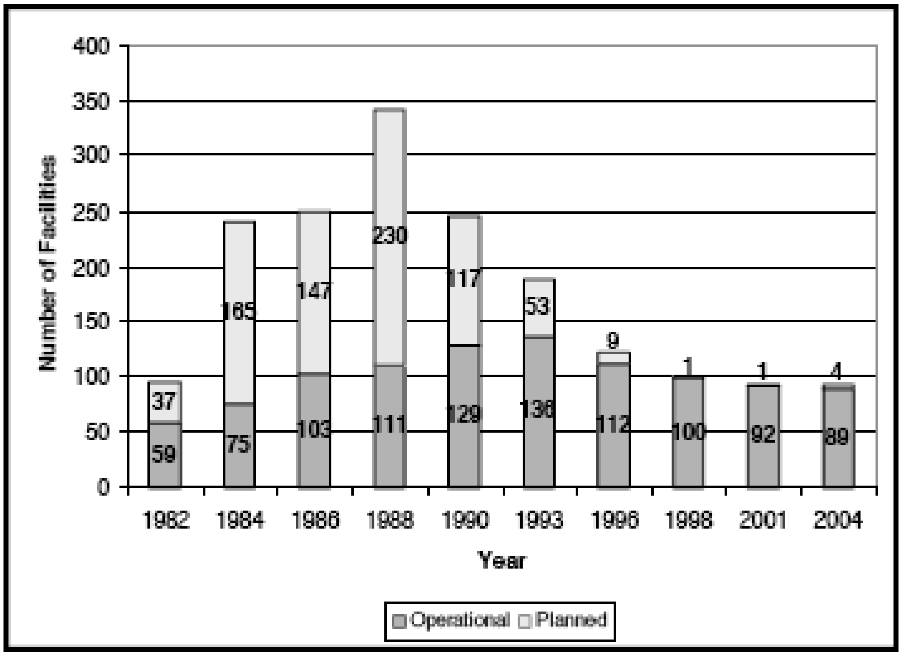


Exhibit 4: Operational and planned WTE facilities in the US from 1982 to 2004[41]

WTE plants began to compete for waste while energy and tipping fee revenues declined.[42] Tipping fees are the price charged to dispose of a ton of MSW. The industry came under substantial economic pressure in the 1990s. This resulted in the restructuring of waste contracts with customers, a reduction of tipping fees and waste volumes, solicitation of special wastes to make up for lost revenues, the restructuring of debt and the creation of other secure sources of revenues. These included landfill surcharges, property tax assessment, or waste generation fees. Small, marginal modular facilities, in particular, were closed. Total industry processed-volume stagnated, but did not meaningfully decline, as plants were upgraded to larger size.[43]

More recently, the gap between WTE facility tipping fees and landfill tipping fees has narrowed. Landfill tipping fees have risen due to land scarcity, increasing transport fuel costs, and tighter environmental regulations. The rise in energy prices, popularity of "green power", and the rise in the cost of metals and materials have eased the pressure and reversed the decline in WTE tipping fees.[44]

Throughout the 1990s and the start of the 21st century, the WTE industry experienced a spate of consolidation, accompanied by the rise of more private operators and owners. At present two private firms, Covanta and Wheelabrator own 50% and operate 75% of the 88 WTE facilities in the US.[45]

The Potential for WTE In Puerto Rico

There are a number of benefits that Puerto Rico could realize from adopting WTE technology. In addition to tipping fees, WTE plants also derive revenue from the resale of metals and energy production. The recent, dramatic rise in the price of metals, which has encouraged new investment in metals harvesting technology, has extended recovery to the non-ferrous category, particularly aluminum, and man-made materials recovery. A third important revenue stream for WTE projects, the sale of residual ash, is expanding in the continental US. 23% of US facilities benefited from the sale of ash in 2004.[46]

US proposals for the adoption of a carbon tax or a carbon-credit trading framework may also make WTE an attractive solution for Puerto Rico. The Energy Policy Act of 2005 classified municipal solid waste as a renewable energy source when used to produce electricity. Therefore, WTE is eligible for the Production Tax Credit (PTC) or the Renewable Energy Production Incentive (REPI). The latter is subject to federal appropriation.

The ability to produce energy internally is important for Puerto Rico, because it lacks domestic energy resources. [47] 90% of oil, Puerto Rico's primary input for power generation, is imported from US and Caribbean suppliers. [48] The price of traditional hydrocarbons fluctuates based on factors such as global supply and demand fractures and geopolitical instability[49]. The stream of MSW into a WTE facility is not affected by these factors. Therefore, the price of energy produced by WTE facilities will remain stable over time. The cost of electricity on the island, for retail customers, is currently $0.065/kWh, which is supplemented by a $5 monthly charge.[50] Demand has been increasing rapidly in the past decade.[51] Exhibit 5 illustrates Puerto Rico's increased use of energy since 1980.

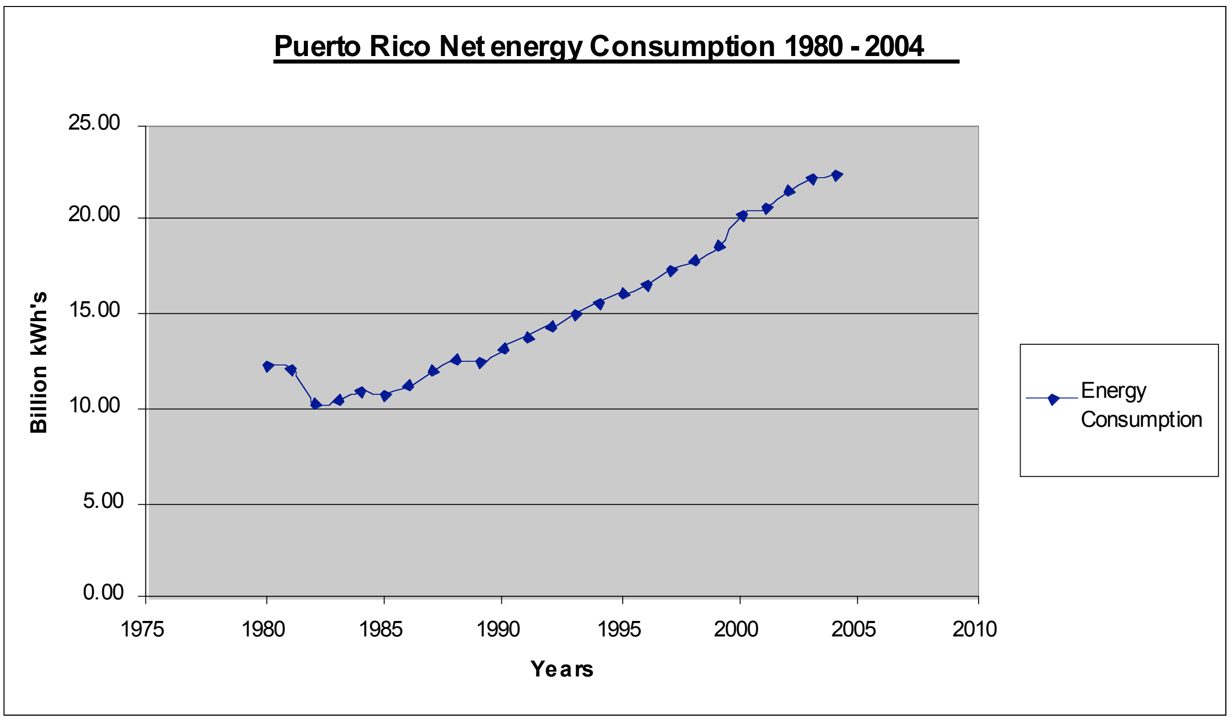


Exhibit 5: Puerto Rico net energy consumption from 1980 to 2004[52]

WTE plants in the US generate an average of 34.3 MW of electricity per plant, of which 6.1 MW (17.7%) is used to power the plant itself.[53] The excess electricity is typically sold at wholesale rates back to the grid, creating revenue for the plant.[54] The Puerto Rico Electric Power Authority (PREPA) has sole control of the electricity generation and sales for the island. Strong labor unions have limited the utilization of co-generation, and agreements with independent power producers[55] to diversify the island's fuel mix have been stymied. However, PREPA does work with some other vendors in the purchase and sale of electricity on the island. PREPA recently signed a 22-year contract for the purchase of liquefied natural gas with EcoElectrica[56].

Public agencies and private partners in WTE projects often make concessions to local communities and residents to build support for WTE facilities. Covanta Energy, the owner of a WTE facility on Oahu, Hawaii supports a variety of community events ranging from high school sports and science fairs to food drives, in addition to employing local vendors where available.[57] In Bermuda, the construction of a WTE plant resulted in the contemporaneous establishment of an air quality monitoring system for the island.

Other benefits may be offered to improve the community and its environmental quality of life.[58] Examples include free surface and groundwater testing, more monitoring wells, free water supply replacement if problems occur, public reports of test results, and control over illegal dumping. Community benefits might include stricter speed limits, money set aside for roadwork and maintenance, traffic agreements, landfill remediation, or park construction. Citizens may also be offered free garbage pickup and support ambulance and fire response.[59]

Additionally, citizens may be offered monetary benefits. To site a WTE facility, it may be necessary to compensate local property owners for any diminution in value they experience as a result of the facility. Some plant owners provide low-interest housing loans to residents who relocate, establish a special fund for any unforeseen problems, or set aside money to fund the education and operation of a local citizens' oversight committee.

III. PUBLIC CONCERNS AND OPPOSITION TO WTE

Public Health Concerns

Despite the industry's global growth in the 1990s, significant public opposition to WTE facilities remains. In particular, citizens worry that the plants may increase ambient levels of dioxin and other air pollutants. The same concerns were raised in Puerto Rico when WTE plants were proposed in the 1990s.[60] In 2004, Puerto Rico's Medical Association's Environmental Health Committee said a WTE plant would pollute the air with dangerous levels of dioxin.[61] Dioxin emissions are typically associated with excess risk of cancer, reproductive effects, and endocrine system effects.[62] Studies have shown that workers exposed to high levels of dioxin over many years have a higher risk of cancer.[63] Tests designed to examine reproductive and endocrine effects in humans show inconsistent results,[64] but experimental data indicates that dioxins affect the endocrine and reproductive systems in animals and humans."[65]

Although concern remains about dioxin emissions from WTE plants, levels have actually decreased dramatically over the past two decades as a result of improvements in pollution control technology. Exhibit 6 provides a comparison of dioxin emissions in the US from WTE and other sources from 1987 to 2002. Exhibit 7 illustrates the decline of WTE as a contributor to dioxin emissions.

Category	1987[a]	% Of Total	1995[a]	% Of Total	2002[a]	% Of Total
Waste Incineration						
MSW	**8877**	**77%**	**1250**	**71%**	**12**	**0.96%**
Medical Waste	2590	22%	488	27%	7	0.54%
Sewage sludge	6	0.05%	14	0.84%	14	1.17%
Hazardous Waste	5	0.04%	5	0.33%	3	0.03%
Total Incineration	*11478*	*82%*	*1758*	*54%*	*37*	*3%*
Non-Waste Incineration						
Backyard barrel burning	604	4%	628	19%	628	56%
Metal smelting	955	6%	301	9%	35	3%
Cement kilns	131	0.94%	173	5%	25	2%
Land-appl'd sewage sludge	76	0.55%	76	2%	76	6%
Pulp and paper	372	2.67%	23	0.71%	15	1%
Coal-fired utilities	**50**	**0.36%**	**60**	**1%**	**60**	**5%**
Industrial wood burning	26	0.19%	27	0.85%	27	2%
Residential wood burning	89	0.64%	62	1%	62	5%
Diesel trucks	27	0.2%	35	1%	35	3%
Other	137	0.98%	103	3%	100	9%
TOTAL (ALL SOURCES)	***13949***	***100%***	***3252***	***100%***	***1106***	***100%***

[a] Dioxin/furan emission units of toxic equivalent quantity (TEQ) in grams, using 1989 toxicity factors; total may not add up to 100 % due to rounding

Exhibit 6: Sources of dioxin emissions in the US, 1987-2002[66]

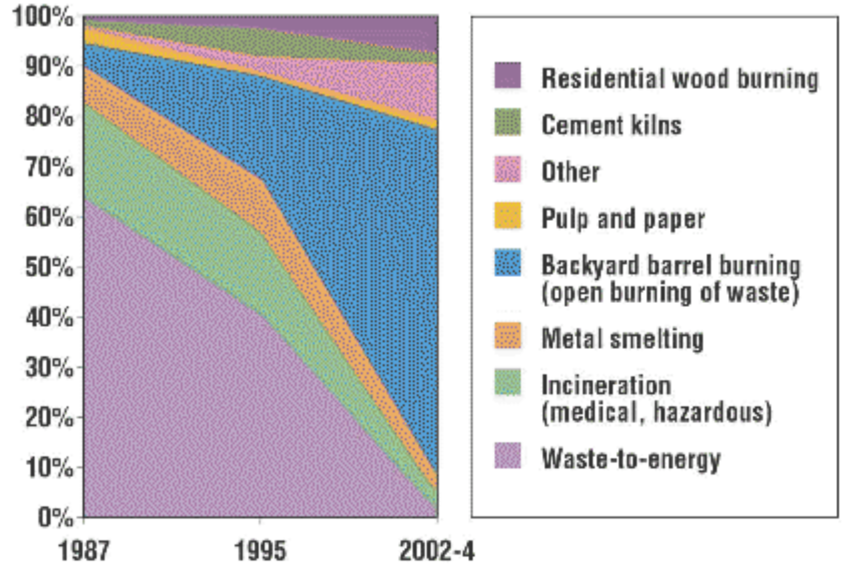


Exhibit 7. Distribution of dioxin sources in the US, 1987-2004[67]

Concerns also exist about the management of WTE byproducts. Citizens are afraid a WTE plant would produce hazardous waste that Puerto Rico is unequipped to handle because it is an island with limited space to dispose of such material.[68] A member of the Medical Association's Environmental Health Committee, claimed that a WTE plant would discharge polluted water into the waterways of Puerto Rico and in turn contaminate the environment.[69] However, very few of today's WTE combustion plants produce liquid effluents that need to be discharged, other than the standard wastewater discharges from normal use, such as in restrooms.[70] Wet scrubbers are the only potential source of liquid discharge at a mass burn WTE plant,[71] but few facilities still employ this pollution control technology. These facilities must treat their effluent discharges so that contaminants are within the allowable regulatory limits before the water is discharged to the local wastewater treatment plant. Wet scrubber technology is relatively old, and would probably not be used in Puerto Rico.

General concerns about WTE include decreases in property value,[72] unpleasant odors,[73] visual impacts,[74] noise impacts,[75] increases in traffic to and from the plant[76] and the size of the plant.[77] There are also concerns about decreases in recycling with WTE, increased cost of waste disposal and decreases in tourism. These concerns will be addressed in subsequent sections of this report.

Characteristics of Public Opposition to WTE

Public opposition and citizen protest may prevent the use of WTE technology. Opposition to WTE plants typically emerges out of grassroots action and community activism.[78] The power of localized collective action to derail WTE projects can be significant.[79] After facing public scrutiny, officials in Monmouth County, New Jersey, held a referendum where voters rejected a waste-to-energy plant.[80] In Alameda, California, citizens and environmental justice groups in 2003 convinced Alameda Power and Telecom to reject a proposed MSW gasification plant and issue an order excluding this technology as an energy source in the future.[81] This decision, against the recommendations of their own consultants, resulted from intense lobbying from opposition groups about environmental and health concerns.[82] Similarly, a company proposing a WTE facility in upstate New York bowed to intense public pressure and recently honored a pledge to halt the project without community support.[83] Citizens first persuaded town officials to withdraw support and then trained upon the plant owners.[84] The plant would have processed a significant share of New York City's solid waste via rail car delivery.

NGOs stimulate local efforts and help opposition coalesce around issues. In 2003 at Chowchilla, California, opposition to a proposed medical waste incinerator sprang from an NGO's analysis of potential plant emissions and its subsequent campaign to inform local residents.[85] The NGO also played a role in meetings with city officials, convincing them to seek more emissions data from the plant owners, who ultimately withdrew their application. Likewise for public officials, a critical part of a community organization or NGO's mission is public education. A study of citizens' attitudes toward a proposed WTE facility near Charlotte, North Carolina found surprisingly low opposition and resistance, but over 2/3 of the sample were unaware of the very proposal itself.[86] The lack of public knowledge may be due in part to the absence of any significant community organization or pressure groups.

Local opposition may also be activated by outside groups or actors whose support strengthens local organization. People from all disciplines, including health professionals, scientists and state and national environmental action organizations, joined with citizens and local groups to defeat a proposed plant in Monmouth County, New Jersey.[87] A protest movement against an industrial waste incinerator near Coimbra, Portugal, illustrates this potential; opposition grew through alliances and linkages forged with broader social movements.[88] The local opposition became more heterogeneous and expanded by allying with new supporters who had ties to larger national and global environmental and social justice movements. These ties helped opponents become likened to a political struggle and have enabled it to withstand criticism and internal tensions.[89]

IV. WTE TECHNOLOGY

Combustion and gasification are the two dominant WTE technologies available today. Combustion is a mature technology and accounts for most of the 600 WTE plants in operation worldwide.[90] Gasification is a newer technology by contrast, but is increasingly common, with over 100 plants installed, primarily in Japan.[91]

Combustion and gasification utilize similar processes. Waste is delivered by truck and is deposited into a large pit near the plant.[92] The waste is loaded by crane into a hopper and then placed onto moving grates, which transport the waste into combustion or gasification chambers.[93] The heat generated during the combustion or gasification process is used to boil water in a closed boiler system.[94] The steam spins turbines, which in turn produce electricity.[95] The exhaust gases that are generated through the combustion process contain several air pollutants. These gases are transported through a flue, or a series of exhaust pipes and chimneys, and are cleaned using a variety of emissions control technologies before they are emitted from the plant.[96] As a result, emissions from WTE plants fall well below EPA's allowable thresholds for air pollutants.[97] Aside from gaseous emissions, the other byproduct from WTE plants is the residual ash remaining after incineration. The ash byproduct is collected for metals separation or disposal.[98] Exhibit 8 illustrates the layout of a typical mass burn combustion facility.

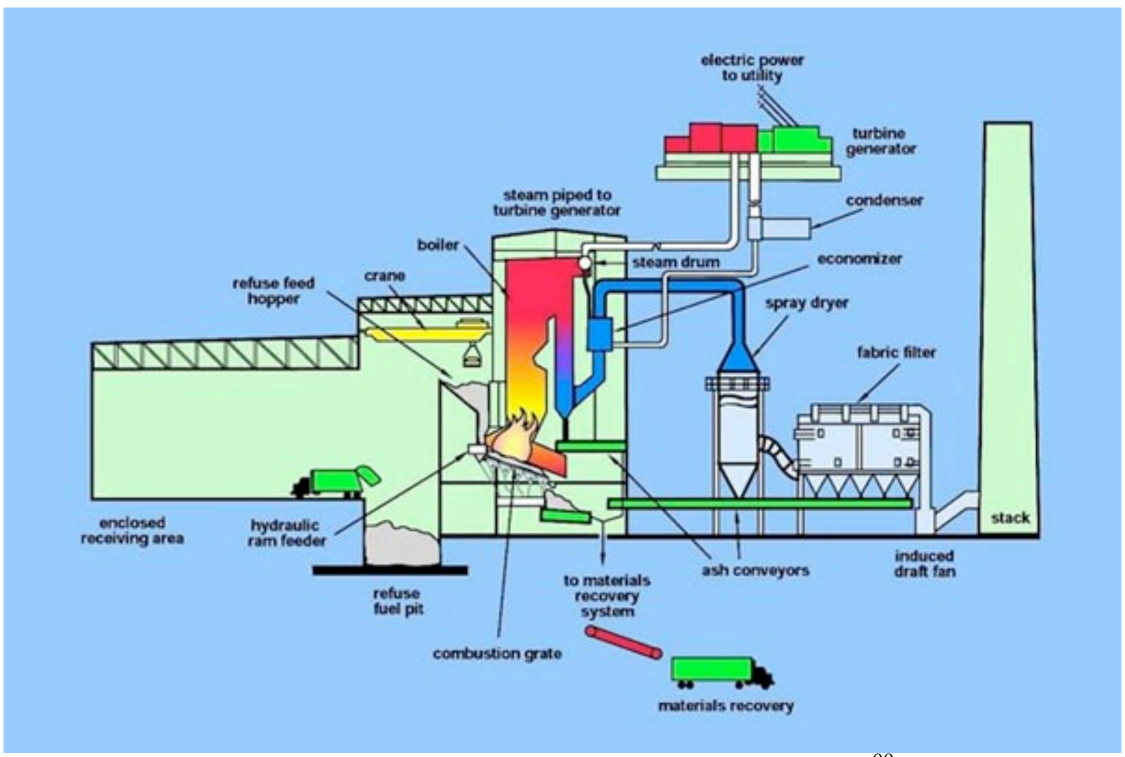


Exhibit 8: Schematic of a mass burn WTE facility[99]

Combustion

Combustion is the classification given to a variety of WTE technologies. The main difference between combustion methods relates to how the waste is processed prior to combustion. Mass burn technology requires limited processing to remove bulky, hazardous and/or valuable objects.[100] Refuse-derived fuel (RDF) technology involves more extensive processing; waste is shredded with rotating hammers and ferrous metals are recovered with a magnet before incineration. The choice of mass burn or RDF technology has implications on processing capacity, cost and the efficiency of fuel produced. RDF can also be used as a feedstock for gasification plants.

Further distinction is made between different combustion technologies based on the type of grate utilized to move MSW into the combustion chamber. The grates shift and move the waste downward into the hottest part of the boiler.[101] The shifting grates ensure proper mixing and thorough combustion of the waste. Exhibit 9 provides further information about combustion technology. Section V will present an economic model that assumes adoption of mass burn combustion technology in Puerto Rico.

Gasification

Gasification decomposes MSW by heating it in the absence of oxygen in stages differentiated by temperature, to produce a gaseous, fuel rich product.[102] This "syngas" is then combusted, providing energy to the steam turbine. Incinerating the waste at increasing temperatures up to 1700 ºC allows for the separation of valuable materials in the MSW. Besides the fuel that is produced, slag, a solid byproduct, is also produced. Slag has a variety of uses in the construction and building industries.[103] Exhibit 9 provides a further breakdown of the specific differences between combustion and gasification technologies.

Technology	MSW Gasification	Mass Burn Combustion
Definition	• This process converts any carbon-containing material into a synthesis gas composed primarily of carbon monoxide and hydrogen, which can be used as a fuel to generate electricity or steam. • Is a low oxygen process. • The high temperature in the gasifier (1400° C to 1700° C) converts the inorganic materials in the feedstock (such as ash and metals) into a vitrified material resembling coarse sand. Valuable metals are concentrated and recovered for reuse. The vitrified material, generally referred to as slag, is inert and has a variety of uses in the construction and building industries.[104]	• MSW incineration. • Limited processing removes bulky (1% of waste stream), hazardous and/or valuable objects ($ recovered). • MSW is moved on grates and burned in a furnace. • Heat from combustion chamber used to boil water → steam spins turbines. • Pollutants in flue gases can be cleaned. • Fly ash (10-20% of total ash) is landfilled. • Bottom ash (80-90% of total ash) is landfilled or treated and sold.
Specifications (energy output, throughput tonnage, etc)	• Two types of MSW gasifiers, fixed bed and fluidized bed • Modular units, many sizes, lines usually run simultaneously. A typical facility can take in up to 1000t/d. • 500-600 kWh per ton/day. • Energy created is captured to run the facility and excess is sold back to the grid. • Ash generated is around 15%-25% of MSW processed.[105]	• 200 to 3,000 t/day. • Approx. 525 kilowatt-hours (kWh) per ton of MSW (+/-75kWh/t)[1]. • Higher efficiency possible through steam cogeneration and onsite electricity use. • Small ash waste stream (10% of original waste stream)[106]
Emissions	• SO_2, NOx, CO_2 • Dioxins/Furans (PCDD/PCDF's) • Because gasification takes place in a low oxygen environment, these pollutants are emitted below levels mandated by federal standards[107]	• Particulate Matter • Acid Gases (SOx, HCl, HFl) • NOx, primarily NO and NO2 • CO, organics/Total Organic Carbon (TOC) (Products of Incomplete Combustion)
Issues	• Waste needs to be presorted to remove bulk items • Waste needs to be shredded • Large capital expenditure	
Examples	• EBARA Corp. in Asahi Clean Center, Kawaguchi City Japan	• Bermuda Plant (Von Roll) • SEMASS RDF plant in Massachusetts • Covanta plant in Newark, NJ • Hawaii Plant

Exhibit 9. Combustion vs. Gasification

WTE Emissions Control Technology
Technological advancements over the past two decades have dramatically reduced emissions from WTE facilities. Many US WTE facilities utilize air pollution control systems that bring emissions well below EPA standard levels. A WTE plant in Puerto Rico would most likely install dry-scrubbers, an active carbon injection system and a bag filter[108], three pollution control technologies commonly installed at new WTE plants.[109] Carbon injection removes mercury and NO_x from emissions, bag filters remove particulates and heavy metals, and dry scrubbers clean out pollutants like hydrochloric acid and sulfur dioxide. These measures consistently maintain emission levels and odors below EPA standards.[110] Some companies place an additional scrubber after the bag filter, but because WTE facilities emit well within safety standards, this is not necessary.[111] Exhibit 10 presents a schematic of the emission control systems that may be installed at a WTE facility.

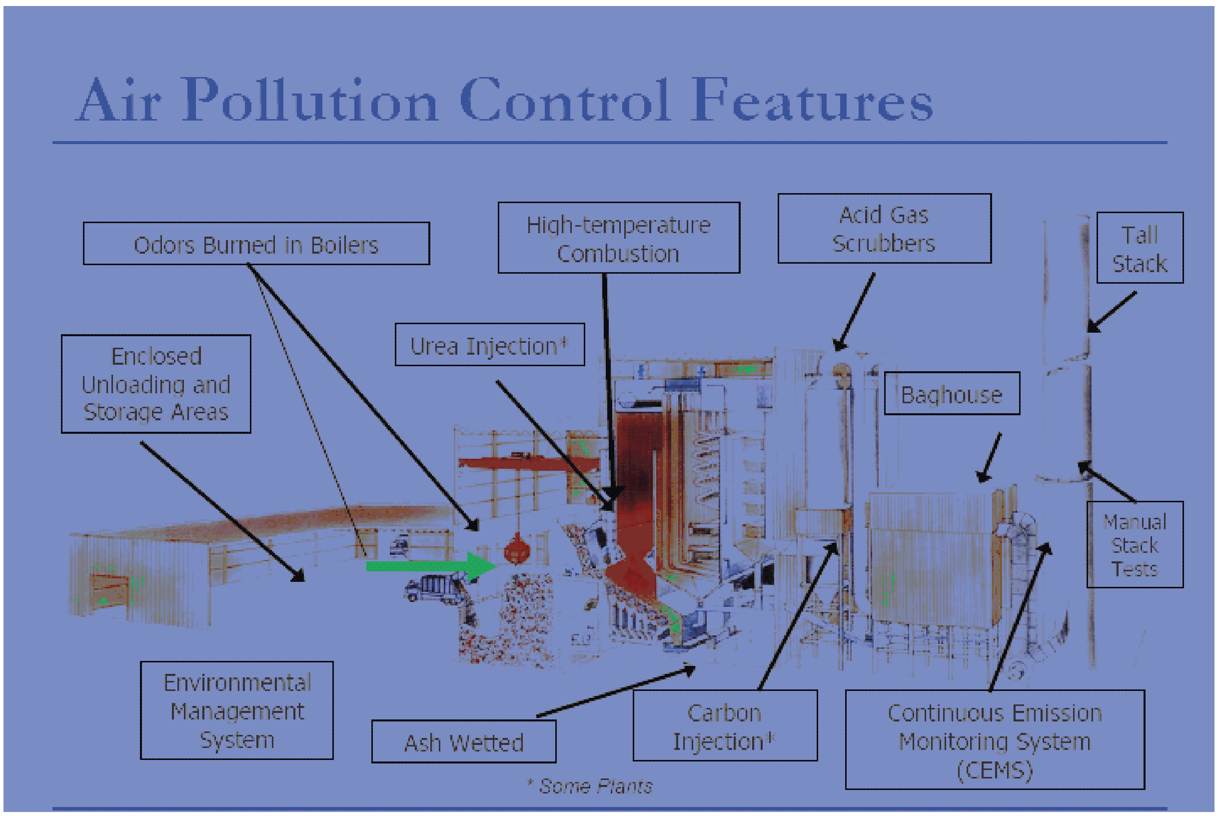


Exhibit 10. Covanta air pollution controls at its Hempsted, NY, facility[112]

Exhibit 11 presents the permitted and average emission levels for several emission streams for the 95 US facilities in 2001 with basic standard emission controls in place.

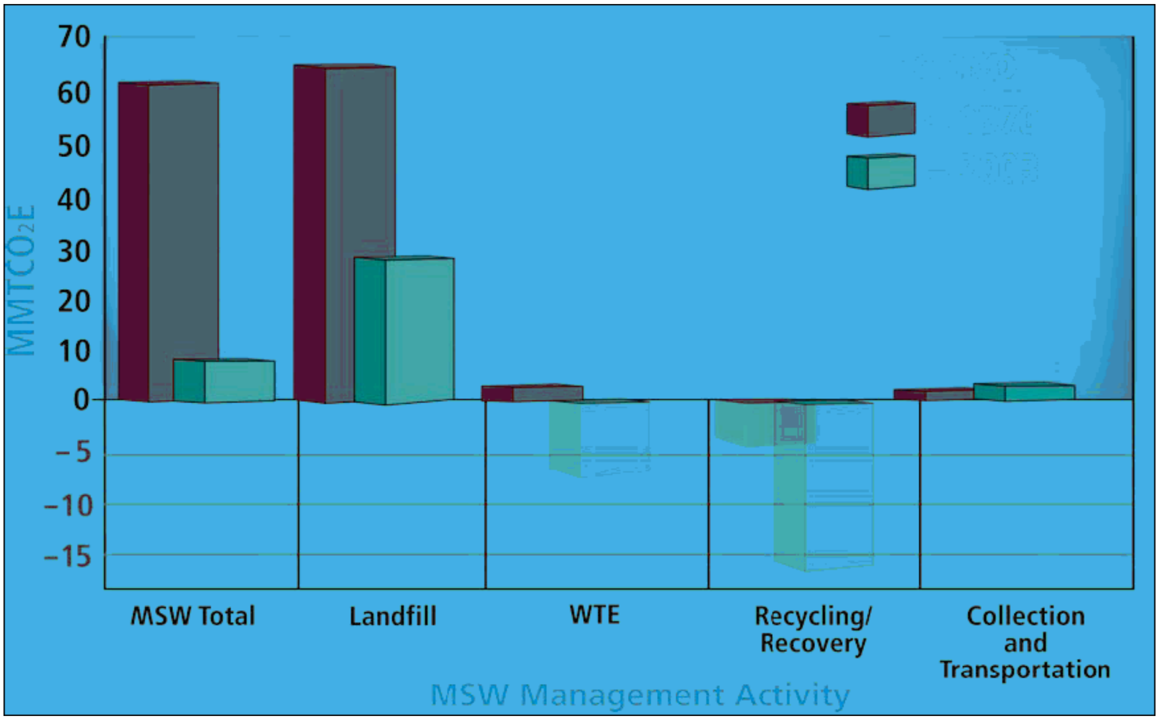
Pollutant	Average Emissions	EPA Standard	Unit
Dioxin/Furan, TEQ Basis	0.05	0.26	ng/dscm
Particulate Matter	4	24	mg/dscm
Sulfur Dioxide	6	30	ppmv
Nitrogen Oxides	170	180	ppmv
Hydrogen Chloride	10	25	ppmv
Mercury	0.01	0.08	mg/dscm
Cadmium	0.001	0.020	mg/dscm
Lead	0.02	0.20	mg/dscm
Carbon Monoxide	33	100	ppmv

Data are reportd for 7% oxygen, dry basis, and standard temperature and pressure
ng/dscm: nanogram per dry standard cubic meter
mg/dscm: milligram per dry standard cubic meter
ppmv: parts per million dry volume

Exhibit 11: Comparison of 2001 emissions from 95 US WTE facilities and US EPA Standards[113]

The difference in emission between mass burn and gasification plants is negligible, with gasification emitting slightly fewer dioxins. Nonetheless, as Exhibit 11 illustrates, levels from modern facilities are very low with both technologies. WTE represents less than 1% of known US dioxin emissions per year.[114] Moreover, emissions in the US have been decreasing steadily over time. From 1995 to 2005, total dioxin emissions fell from 4860 grams to 6 grams.[115]

Another possible concern regarding WTE facilities is their contribution to greenhouse gas (GHG) concentrations in the atmosphere. Landfills emitted 28.2 $MMTCO_2$ of GHG in 2003, but WTE facilities' emissions were reported at -7.1 $MMTCO_2$ because energy created by WTE facilities offset emissions from fossil fuels. WTE does produce a small amount of CO_2, but this represents about 0.25% of all CO_2 emissions from the energy sector and waste combustion industry.[116] Exhibit 12 provides the net greenhouse gas emissions from several sources for the period of 1970 to 2003 in the US.



MMTC0$_2$: million metric tons of carbon dioxide equivalent

Exhibit 12: Net greenhouse gas emissions from US MSW, 1970-2003[117]

Ash is the primary byproduct of a WTE plant. The ash contains low levels of leaching heavy metals, that under RCRA are considered non-hazardous.[118] Ash may be put to a variety of uses from landfill cover, construction aggregate, and in shoreline protection and marine reclamation projects, such as artificial reefs.[119]

WTE and Recycling

There is concern that focusing attention on incineration could be detrimental to recycling and waste reduction efforts.[120] In Puerto Rico, some officials see WTE as a waste of money and an inefficient use of resources, which could be better spent on promoting recycling programs.[121] These officials are backed by academics who claim that recycling and reuse of solid waste is the most economically and environmentally sound way to deal with solid-waste problems and that WTE could work against other waste reduction measures.[122] This is related to concern about the ability to maintain a substantial waste flow for WTE. A number of cities around the US have built large incinerators that do not run at capacity. These plants overestimated the amount of waste they would generate and were further hurt by increased recycling. This has lead to increases in tipping fees in these cities.[123]

Recycling in conjunction with WTE may promote recycling more than other MSW management options.[124] In the United States the average recycling rate is 28% in communities without WTE and 33% in communities with WTE.[125] When incombustible recyclables, such as glass and metals, are taken out of the waste stream the WTE plant runs more efficiently, generating higher revenues.[126] For example, aluminum ore is expensive to mine and burning it produces no energy and may actually clog the incinerator.[127] In addition, although paper and plastics can be processed, WTE plants operate more efficiently when these materials are removed for recycling.[128] In the US, 77% of WTE plants have onsite ferrous metal recovery programs, most of which occur post combustion.[129] Since ferrous metals are collected efficiently at the WTE facility there is no need for a curbside program.[130] Also, 43% of facilities have onsite recovery of nonferrous metals, plastics, glass, white goods, and combustion ash.[131]

Staffing a WTE Facility

WTE facilities require a breadth of skilled employees for successful, compliant operation. Operations employees include skilled technicians, such as electricians, boiler operators, safety inspectors, and skilled laborers, such as crane operators and line operators. WTE facilities also employ a gamut of other professionals: quality control managers, environmental engineers, maintenance engineers, business managers and facilities managers are all needed for operations. The number of employees at a typical WTE plant varies by size as well as the specific technology being used. Large-scale WTE combustion plants in the US can process up to 3,000 tons of waste per day[132] in multiple boilers and generate roughly 525 kilowatt hours of electricity per ton of waste (kWh/t).[133] For example, the Covanta Essex plant in New Jersey processes about 2800t tons per day (tpd) of waste and employs approximately 80 to 90 workers.[134] Some small plants exist with capacities under 100 tons per day, although they operate less efficiently than the larger plants.[135] Furthermore, the number of small, modular plants has decreased in recent years due to "economic and operating failures."[136] Gasification plant capacity is lower than combustion plant capacity, with each gasifier/boiler system capable of processing approximately 240 tons per day of waste.[137]

Reliability of WTE Technology

WTE plants are designed to last for several decades.[138] However, the gases created during combustion are corrosive and can damage many parts of the plant, including the boilers, ducts, and emissions control equipment.[139] Periodic maintenance operations are therefore needed to replace or repair parts that are damaged by the gases. Plant operators schedule major outages (shutdowns) for each boiler once a year so that these maintenance operations can be performed.[140] During the outages, maintenance personnel fix any leaks in the boiler tubes and address other equipment malfunctions.

The scheduled outages usually improve plant operation for several months, however, they do not negate the need for additional nonscheduled outages to address problems that arise throughout the year.[141] Nonscheduled outages are typically shorter in duration than scheduled outages, and occur most frequently with old boilers, especially in the months preceding a scheduled outage. In other words, the longer a boiler has been running, the more likely it will require a nonscheduled outage.[142] Plants often anticipate each boiler to have 2 to 3 nonscheduled outage days per month. Often these shutdowns are not necessary and do not occur.[143]

Maintenance operations at a WTE plant usually cost several million dollars per year, the majority of this cost is incurred during the scheduled outages. Covanta's Essex County, New Jersey plant spends $10-$12 million per year on outages, approximately 85% of which is spent during the scheduled outages.[144]

Operational Issues

Although WTE technologies are reliable when the proper maintenance operations are performed, they require a large amount of monitoring and addressing day-to-day operational issues.[145] As an example, large pieces of noncombustible waste may be accidentally loaded into the boilers.[146] Workers must remove these objects by hand while keeping the boilers online as much as possible to maintain a constant revenue stream.[147] If a boiler needs to be shut down, the plant forgoes revenue.

Each plant's operation depends largely on the particular waste stream that it processes.[148] For example, WTE plants in the northeastern US have to address the issue of frozen waste in the wintertime, which burns very slowly and inefficiently.[149] For Puerto Rico, there may be issues associated with the waste stream in the particular area in which a plant is sited. Waste inventories of these areas may provide an indication of the kinds of challenges that will be faced by the plant. By understanding the composition of the waste stream, local officials can make informed decisions regarding waste management budgeting, designing WTE facilities, buying new equipment, and estimating space and personnel needs. A waste inventory can also be used to provide accurate estimates of energy generation from a WTE facility. Further, this data can be used to measure whether waste management goals have been met and whether recycling programs are successful. Waste inventories can be compared across communities to evaluate what strategies work best.[150]

Daily and seasonal inconsistencies in the waste stream are also an issue. Inconsistent waste streams require constant monitoring of the combustion process and adjustments to the air intake vents in different sections of the boilers to ensure even combustion.[151]

V. ECONOMICS OF SITING A WTE FACILITY

There are two basic financial considerations related to siting a WTE facility: the cost of the facility relative to the cost of a landfill and how the WTE facility will be financed. Stakeholders, including the public, public officials, consultants and investors, will be interested in a long term cost comparison of landfills and WTE facilities to gauge whether the WTE project should proceed and be financed.

Comparison Criteria for WTE Cost and Landfill Tipping Fee Cost

WTE projects will prove viable if the landfill tipping fee exceeds the WTE tipping fee. Additionally, WTE revenues are augmented by sales of electricity to the local grid.

Landfill Tipping Fee
Landfill tipping fees cover land purchase, landfill construction with environmental controls, equipment and labor for the operation and future closing of the landfill, as well as a profit for the landfill operator and investor. The per ton tipping fee is therefore the total production cost, a benchmark which can be used for comparison to a WTE tipping fee. Landfill tipping fees may actually underestimate the true and full economic future cost by excluding the cost of a potential adverse event, such as a cracked liner, which may result in unexpected leaching.[152]

In Puerto Rico, the average tipping fee for non-compliant landfills has been estimated to be $37.[153] Tipping fees in Puerto Rico are rising, however, because of land scarcity and the cost of new environmental controls. Considering such additional cost factors, compliant landfill tipping fees are estimated to be $34 to $72 per ton without landfill gas recovery, and $43 to $90 per ton with full landfill gas recovery.[154] The wide range of estimates reflects the differing sizes and sophistication of compliant landfills.

In comparison, the average tipping fee in Florida is $44 per ton for Subtitle D compliant landfills. Florida has similar characteristics to Puerto Rico such as a high groundwater table, high population density, and a warm and humid climate.[155] Based on this analysis, we will assume, for the purposes of comparison, that tipping fees for compliant landfills in Puerto Rico will be at best $45 per ton, and will most likely be in a range of $45 to $60 per ton.

WTE Tipping Fee
WTE tipping fees are the price charged to dispose of a ton of MSW at a WTE facility. The revenues generated from the sale of byproducts reduce the costs of operating a WTE. Total costs include operating and capital costs of the facility, plus the costs charged by the operator and investor; the benefits include the proceeds from the sale of energy and materials.

The prospective WTE tipping fee is the best estimate of the total production cost of a WTE facility. There are two basic methods of estimating the WTE tipping fee of a new WTE facility in Puerto Rico. First, we can examine the current and historic tipping fees of other WTE plants in the US This is a simple and adequate top-down method, which will generate a solid estimate range for WTE tipping fees for Puerto Rico. Second, we can construct a more complex financial model of a WTE project for Puerto Rico, and generate the WTE tipping fee from the bottom up, making a broad range of specific assumptions about capital construction, operating and financing costs and energy and materials revenues. The first method is a good way for stakeholders to initially compare landfills and WTE facilities as basic waste disposal alternatives. The second, more rigorous method will be required when the project is at the stage where investors and financing are being sought.

In the US, average WTE tipping fees for 86 facilities operating in 2003 vary greatly by region:

Region	**2003 Tipping Fee**	**Number of Facilities**
Northeast	$60.76	39
South	$47.76	24
Midwest	$52.00	16
West	$51.79	7
Total	$54.21	86

The US average is $54.21. The highest fees of $60.76 are in the Northeast where population is dense and land is relatively scarcer.[156] The WTE tipping fee is $57 at the Broward County Waste and Recycling Center in Fort Lauderdale, Florida, where geographic conditions are similar to Puerto Rico. See Case Study 1 for more information about the Broward WTE facility. The tipping fee is $55 at the Covanta Honolulu Resource Recovery Venture in Kapolei, Hawaii.[157] Case Study 3 provides more information on this WTE facility. Based on these top-down figures, an estimate range for Puerto Rico for WTE tipping fees is $50 to $60 per ton.

We created a model, which estimates from the bottom-up, that WTE tipping fees will be in the range $54 to $62 in Puerto Rico. Below we explain in brief how we arrived at these estimates. A more detailed explanation of the model is provided in Appendix C.

Using our project model, we made the following basic volume, rate and cost assumptions for a WTE facility:

Daily Capacity	2,500 tons
Capital Cost	$170,000/per daily ton
Capital Cost	$425 million
Landfill Tipping Fee	$45/ton
Borrowing Rate	5.75%
Debt Financing	75%
Equity Financing	25%

WTE facilities are large, expensive facilities. The cost of a WTE facility is very sensitive to small changes in assumptions. Project profitability is largely affected by slight variations of basic assumptions, such as capital cost, the landfill tipping fee paid to dispose of the ash byproduct, the electricity price received, the borrowing rate and the relative amount of debt and equity financing. Using these assumptions as model inputs, the project model generates a "required" WTE tipping fee, which covers the facility's net production costs and provides an acceptable profit to investors. To demonstrate further the sensitivity of the project to changes in assumptions, we present here two cases, the "conservative case" and the "realistic case." By varying two critical, additional inputs to the model, Electricity Price Received, and Electricity Incentive Payment, a renewable energy subsidy from the Energy Policy Act of 2005, we arrive at two quite different WTE tipping fees:

	Conservative Case	*Realistic Case*
Electricity Price Received	$0.052/kWh	$0.059/kWh
Electricity Incentive Payment	$0.000/kWh	$0.018/kWh
Required WTE Tipping Fee	$62/ton	$53/ton
Project Internal Rate of Return	16.6%	16.6%

In the "conservative" case, we assumed that the WTE facility receives 80% of the average electricity price in Puerto Rico.[158] Further, we assumed that the facility does *not* receive a federal Electricity Incentive Payment of $0.018/kWh, because that payment is subject to periodic federal appropriations. The result is that the required WTE tipping fee is $62/ton.

In the "realistic case, using the same basic volume, rate and cost assumptions, we change the assumptions for the Electricity Price Received from $0.052/kWh (80%) to $0.059/kWh (90%), and for the federal Electricity Incentive Payment from $0.000/kWh to $0.018/kWh. The result is that the required WTE tipping fee drops to $53/ton. In each case, the Project Internal Rate of Return is the same at 16.6%, which will be attractive to investors.

The difference between the "conservative" case and the "realistic" case is that revenue has increased by changing two variables, therefore the required WTE tipping decreases, and becomes more competitive versus the assumption of a $45/ton landfill tipping fee.

In conclusion, landfill and WTE tipping fees in Puerto Rico are estimated to be as follows:

Landfill Tipping Fees	$45/ton to $60/ton
WTE Tipping Fees (Top Down)	$50/ton to $60/ton
WTE Tipping Fees (Bottom Up)	$54/ton to $62/ton

In any jurisdiction, all else equal, as the difference between landfill tipping fees and WTE tipping fees narrows, a WTE facility will be increasingly attractive on a purely financial basis. In order to compare landfill to WTE as a MSW management option, stakeholders, including investors, will need to understand the assumptions underlying the relative costs of each.

On a comparative basis, WTE appears to be cost competitive to landfill in Puerto Rico in both the "conservative" and "realistic" cases. Therefore it would appear that a WTE project is feasible in Puerto Rico, and adequately attractive to proceed to consideration of how it will be financed.

Financing Considerations

The relative costs of landfill compared to WTE communicate the profitability of a WTE facility to stakeholders. A more complex project model than the one presented in Appendix C will be required to give public officials, the public, owners and lenders comfort about long-term project feasibility. Financing concerns will diminish the more feasible and stable the prospects of a successful project.[159]

In general, a WTE project faces certain costs and less certain revenues.[160] The fixed costs include debt service, on-going facility maintenance and facility insurance. It would be ideal for a WTE project to negotiate long-term fixed tipping fees and long-term energy sale agreements, in order to make revenues more certain, thereby lessening the risk and the required internal rate of return for investors. The required return can be expected to range from 15% to 20%, depending upon the structure of the project and the way in which it is financed.[161]

There are a variety of options for financing, owning and operating the project. Debt financing is usually relied upon quite heavily in project capital structures of this type.[162] Because facilities benefit the general public, a WTE project will almost invariably involve debt financing via public sector entities. Historically, the public sector has provided 74.5% of total financing in the US, mainly in the form of bonds (debt), grants or dedicated revenues. The private sector has provided 25.5% of financing, mainly in the form of equity. It is therefore a reasonable assumption that a new WTE project can be approximately 75% debt financed and 25% equity financed. The debt financing is usually a mixture of tax-exempt and taxable revenue bonds that are floated by a government agency, public sector authority or industrial development authority.[163] The tax-exempt bonds are usually general obligation municipal bonds, while the taxable revenue bonds are usually industrial revenue bonds, in which cash flows from the project are dedicated to repayment of bond interest and principal.

In the case of the Broward County Waste and Recycling Center in Ft. Lauderdale, Florida (Case Study 1), the original capital cost was $278 million. It was public debt financed with $220 million of industrial revenue bonds. Private equity capital for 21%, $58 million, of the project came from Wheelabrator, a large, publicly traded waste management firm.[164] In the US it is increasingly the practice for private owners to assume both equity ownership and operating responsibility.[165] Private firms now own almost 50% of facilities, with Public Counties and Authorities owning 19% and 17% respectively.

Despite the US trend is towards private ownership of WTE facilities, it is possible that a special purpose and new entity, with public sector involvement and sponsorship, will be used to finance the facility in Puerto Rico. In this case, the most likely technical form of ownership structure will be joint public-private, in order to qualify for tax-exempt debt financing. [166] The public sector itself may or may not make an equity investment, but will participate in the debt financing. It is also possible that a wholly private entity will be used to finance the facility, in which case the public sector will not be formally involved.

In a WTE project, the debt holders first examine the credit rating of the issuing entity. If the choice is made to issue industrial revenue bonds, which is most typical in current WTE financings, the debt holders will use the project model for comfort about safety of cash flows. If the choice is made to issue general obligation municipal bonds, then the debt holders will look mostly to the credit rating of the issuing entity. The credit benchmark for a municipal entity in Puerto Rico is the credit rating of Puerto Rico itself. Puerto Rico has a Standard & Poors credit rating of BBB, which is relatively low for a government entity.[167] Given recent financings by Puerto Rico, and assuming an additional risk premium for a specific non-Commonwealth public sector entity created for the WTE facility, it is estimated that this facility could be financed at between a 5% and 6% interest rate on a 30 year basis.[168]

In the previous attempt to site and finance a WTE facility in Puerto Rico, the Government Development Bank of Puerto Rico awarded a $67 million line of credit to SWMA for the project.[169] Therefore, it is possible that a new WTE project in Puerto Rico may be able to utilize some debt facilities at a rate that is close to that of the Commonwealth itself, in the mix of its debt financing.

It may be worthwhile to investigate funding techniques used by islands facing similar challenges to Puerto Rico. The WTE facility serving Honolulu and Oahu is privately owned and was funded with $181 million in 1990.[170] Additional funding of $1 million was utilized for installation of a metal recovery system in 1997, and a further $5 million for a periodic turbine overhaul in 2003.[171] In 2003 there was a $43 per ton premium incurred as a result of the debt repayment schedule for the plant.[172] This translated to a cost of $25.2 million.[173] Upon full completion of debt repayment, the plant will be able to run profitably.[174] Case Study 3 examines Hawaii's facility in greater depth.

WTE and Tourism

Tourism is an important aspect of the Puerto Rican economy, representing about 5.5% of GNP,[175] so it is critical to understand the affects of municipal solid waste management systems on this sector. There is evidence that WTE facilities have no effect on tourism. The Canary Islands' decision to build a WTE facility shows the benefit of WTE over landfills in regards to tourism.[176] The Canary Islands rely heavily on tourism, which represents over 30% of their GDP. Similar to Puerto Rico, the Canary Islands have limited land capacity and required a plan that minimized the presence of waste. The decision to use a WTE facility was made to conceal waste and protect the ambience. Jose Melgarejo, the business development manager for Cummins Power Generation said, "Most visitors aren't even aware there is a waste treatment plant here, which is exactly what we wanted to accomplish."[177]

VI. CREATING A PUBLIC EDUCATION CAMPAIGN

A public education campaign could help in the siting of a WTE facility. All sectors of the public should be included in a public education campaign, both those that are for and those that are against WTE technology. Those who live near the proposed site location may have the most immediate concerns and potential opposition to the project. This community should perhaps be the initial target of an educational campaign.

Education could be provided through a partnership with the local government, perhaps a staff community relations specialist, and any private partners involved in constructing or operating the WTE plant. The government should assure that the public is actively involved in the education and is well represented. Private partners with prior experience siting WTE facilities are a potentially valuable resource and guide for the government on how to deal with public participation.

Private partners and the construction firms building the WTE facility may have produced public information documents from previous siting experiences. The government should consider working with these firms, and possibly interested NGOs, to tailor education material to apply to Puerto Rico.

Public officials may choose to involve the community in the planning process. This requires educating the community and eliciting feedback at each phase of the project. Officials in Amsterdam allowed for a six year pre-construction planning period in order to accommodate public feedback before construction of two WTE facilities.[178] The public is likely to appreciate the invitation to be involved in major planning decisions.[179] In addition, by acknowledging that citizens can effectively block the construction of a waste-to-energy facility, officials gain credibility with the public.[180]

The public health risks of WTE plants and similar facilities tend to be overemphasized, because of the involuntary nature of the hazard they potentially pose.[181] Pollution would indiscriminately affect those living near a WTE facility. Public perception assigns a higher risk to potential air and ground pollution because the public feels there is little they can do to avoid harm, short of relocation away from the facility. Thus any attempt to educate by merely presenting the correct numbers and facts about risk may not be persuasive.[182]

Constructive dialogue involves educating and engaging the public as equal stakeholders.[183] [184] Officials should consider learning what risks most concern the public in order to effectively educate them. Citizens are likely to trust officials more when their concerns are acknowledged and they are provided with factual answers.[185] Government officials should consider presenting the potential risks of WTE as well as the potential benefits.

Dialogue with stakeholders could be maintained through mass media campaigns, newsletters and/or a public education center. Commercial style mass media campaigns are effective for informing public opinion on health related issues.[186] Commercial advertisements may be highly effective when accompanied by a toll free number to contact if the listeners have any more questions.

Global Experiences

Communities all over the world have different concerns, priorities and needs. Although, public officials and local authorities can learn about effective WTE facility sitings from previous experiences there is no correct way to site a facility. Therefore, this section examines what other locations in the world have done to involve the public in a WTE siting. The most effective public involvement plan for communities in Puerto Rico will be based on a combination of these techniques. Since community leaders and local public officials know their community needs and concerns the best, they would be ideal candidates to create the public education program.

Connecticut Experience:
A case study of a Connecticut town's efforts to site a recycling facility illustrates the importance of public perception in project development.[187] Participation in political actions against the plant, defined as signing a petition, joining a protest organization or attending a public hearing concerning the proposed recycling center, were all strongly correlated to perceptions of unfairness in the siting process. Citizens with perceptions of inequity in the siting process were more like to participate in oppositional actions.

Dublin Experience:
Local public officials set up a public information center that was staffed with an expert on WTE technology. The center had a library with literature and information packets about all aspects of the plant, including the technology, the positive and negative externalities associated with the plant, and details about community benefits, such as parks and environmental testing. In addition, the center had Internet access and a meeting room.[188]

Public officials created weekly newsletters and dropped them off at all houses in the surrounding community. The newsletters had information about the help center and any upcoming meetings.[189]

Dublin also created a Community Interest Group (CIG) to influence how the environmental impact assessment was carried out and to make sure it addressed the community's concerns. The CIG identified over individual 200 concerns the community had with building the facility. These issues were taken into account when planning the facility. Members of the CIG were picked to represent a diversity of views in the community so that the CIG was comprised of both proponents and opponents of the facility. The CIG held meetings were open to the public, but questions or comments were only allowed at the end of meetings. There were seven official meetings, which addressed issues including planning, environmental law, ecology, health, air quality, traffic and environmental impact assessment. In addition, experts from World Health Organization, Greenpeace, the Institute of European Environmental Policy and Coastwatch Ireland came to speak[190]

Finally, the Dublin City Council held information sessions based on the public concerns. These information sessions addressed topics such as air quality, ecology, health, traffic, statutory processes, incineration technologies and waste management in Dublin.[191]

Amsterdam Experience:
In 1992, the City of Amsterdam created a Waste-to-Energy entity, Afval Energie Bedrijf (AEB), which is run by the city. The siting process was started early giving ample time for meetings, site visits, and a full explanation of the project. Officials in Amsterdam allowed for a six-year pre-construction planning period in order to accommodate public feedback before the construction of facilities. During the process AEB acted in a completely open manner. It withheld no information from the public, NGOs or the government. IPlant managers answered all questions, released emissions projections and provided an

opportunity to visit the sites. Even today AEB publishes an annual report that gives information regarding the financial, social, technical, and environmental details of the plant. AEB involved the citizens through public meetings, and throughout the entire process they made sure their actions respected the viewpoints, concerns and ideas of all the other groups in the community. In addition, they tried to find common ground with these groups. This was found to be particularly important in dealing with environmental NGOs. When the groups understood AEB had the same goals for Amsterdam as they did, the NGOs actually began to support the project. Finally, all communication about the project was done in non-technical language so that non-experts could easily understand all aspects of the project.[192]

Further examples of detailed public education campaigns can be found in the case studies.

VII. CONCLUSION

WTE is an important part of an integrated MSW management plan in Puerto Rico. In the near future, some of Puerto Rico's landfills will need to be decommissioned, upgraded or expanded. In the long run, however, there is little available land to continue to establish new, compliant landfills. Additionally, Puerto Rico would benefit from a domestic, renewable energy supply.

Different technologies are available for use in Puerto Rico, namely combustion and gasification. Combustion may prove more feasible due to its widespread use and simpler technology. Both technologies have been used successfully throughout the world, especially in areas of high population density and scarce land. Environmental concerns about dioxins and other pollutants may be alleviated by the drastic improvements made to WTE control technologies in the past two decades.

Prior to siting a WTE facility, the costs of WTE facilities and landfills must be compared. Tipping fees are an appropriate mechanism for comparison, however, landfill tipping fees must be adjusted to represent the increasing scarcity of land and costs of improving and expanding environmental control technologies. WTE tipping fees may be estimated utilizing the top-down approach of examining WTE tipping fees in similar locations or a bottom-up approach of a model to combine relevant factors, especially those specific to Puerto Rico. This information will be important when financing options are considered.

If WTE is adopted as a MSW management strategy in Puerto Rico, public officials will need to prepare for opposition from the public. Historically, attempts at siting WTE have been unsuccessful due to lack of public support. To avoid such a situation in Puerto Rico, public officials may choose to implement a detailed, meaningful public involvement campaign. Public education about WTE technology, community access to information and forums to voice concerns and citizen involvement in decision-making, may increase the feasibility of siting a WTE facility.

We suggest that public officials in Puerto Rico first educate the public about the current MSW problem and the proposal to include WTE in an integrated solution. Education might occur through television or radio media campaigns, newsletters or public meetings. Next, public concerns should be solicited and addressed by public officials in an open, factual manner at public meetings. All public concerns should be taken seriously, and experts should be called upon to provide factual answers to these concerns.

WTE, in conjunction with other waste minimization and management strategies, could prove an important part of Puerto Rico's new MSW management system. Careful planning and management of a public education campaign will increase the likelihood that a WTE facility is sited in Puerto Rico.

Next Steps And Further Research

WTE could become part of an integrated MSW management plan in Puerto Rico. Before a WTE facility can be sited successfully, however, Puerto Rico should consider the following steps:

1) **Create a timeline.** Many facilities allow up to six years for the planning and design portions of siting a WTE facility. A timeline should also include a public education and involvement campaign to anticipate any negative, potentially detrimental feedback from the community.

2) **Waste inventory and analysis**. Understanding the composition of Puerto Rico's waste stream is a primary step in determining the type and size of facility that should be used in Puerto Rico. A waste inventory would also help model the amount of energy that might be generated at a facility, which could carry some weight in an economic analysis. Appendix A provides a guide for performing regular waste inventories.

3) **Research possibilities of ash resal**e. Landfills on Puerto Rico have limited capacity, so it is important that Puerto Rico research options for the resale of bottom ash. Because ash could incur a landfill tipping fee or produce revenue for the plant, understanding the available options for managing ash will help in the economic analysis of a proposed WTE facility.

4) **Hire a Community Relations Specialist.** A community relations specialist could begin to create a public education plan and timeline as well as work with private waste management companies to start tailoring their already existing WTE plans and materials to Puerto Rico's specific needs.

Case Study 1: Broward County Waste and Recycling Center

Location: Ft. Lauderdale, Florida
Population Served: Approx. 800,000
Facility Type: Mass Burn Combustion
Year Opened: 1991
Company: Wheelabrator Technologies, Inc.
Plant Manager: Christopher Carey
Garbage per day: 2,250 tons per day capacity
Energy per year: 407,408 MW hours
Original Capital Cost: $277,816,000
Original Capital Cost Tons per Day: $123,474
Total O&M per ton: $57.32 (2003)
Total O&M per year: $38185612 (2003)

Community Profile: Middle class community (2003 median household income $42,576).[193] Economy predominately depends on tourism.[194]

What factors lead to the decision to build a Waste-to-Energy (WTE) facility?
Population in Broward County increased by 100 percent from 1970 to 1990 and was projected to continue to increase by 35% from 1990 to 2010. [195] In addition, the waste produced per person was increasing each year, partially due to the increase in per capita income.[196] A county landfill was recently closed and also made a Superfund site.[197] The combined effect of a growing population, an increasing volume of waste and the closing of a local landfill meant the County needed an efficient way to dispose of waste. In addition, the county wanted to find a solution that was environmentally friendly.

What were the major public concerns?
The public was concerned about the large initial financial costs associated with the technology, as well as high tipping fees.[198] They were also concerned about environmental and health impacts from plant emissions.[199] Specifically, concerns existed about the environment because the Everglades cover 2/3 of the county.[200] Mercury emissions in Florida had just been linked to panther deaths and contaminated fish, so the public was also worried about high concentrations of mercury.[201] Another large concern was that the bottom and fly ash would contain toxic metals such as cadmium, lead and chromium.[202] The public worried that landfilling this ash would lead to contamination of the water supply because the water tables are only a few feet underground.[203]

Two small community groups of about 300 people each were created in opposition to the proposed WTE facility.[204] These groups attended the public hearings, distributed fliers and advocated increased recycling instead of WTE.[205] Greenpeace and Clean Water Action also held protests against the building of the facility.[206]

How did the government address these concerns?
Although the initial decision to adopt WTE technology was made by the County Commissioners, the County and City governments worked together throughout the whole process, negotiating over siting, technology, tipping fees and waste delivery.[207] There were over 30 public hearings, which covered topics such as site zoning, bond issuance, air quality permits and wetlands permits.[208] The citizens were allowed to participate in the hearings, which attracted considerable interest. Some hearings had over 300 people in attendance.[209]

In the end, four of the cities in Broward County decided not to use the facility.[210] The other 23 participating cities each chose one representatives to serve on the Resource Recovery Board with the County Commissioners.[211] This board oversaw the construction of the facility and currently oversees the daily operations of the facility.[212]

To avoid adverse environmental impacts, wetland restoration occurred surrounding the facility.[213] In addition, four acres of wetlands were required to be built for each acre destroyed.[214] The county built a park in one city.[215]

In response to high mercury emissions, the facility and the County started a program to encourage hospitals to use non-mercury batteries, which resulted in the removal of almost a ton of mercury a year from the waste stream.[216] The County also persuaded local schools, businesses, offices and residential buildings, to serve as drop off sites for batteries that contain mercury.[217] Just two years after the start of the program over 600,000 batteries and about 153 pounds of mercury had been removed from the waste stream.[218]

What are the technical specifications of the plant?

The Broward plant is a mass burn facility with a designed capacity of 2,250 tons of MSW per day (tpd). There are 3 boilers with a capacity of 750 tons per unit. The boilers achieve 4,700 British thermal units (BTU) per pound.[219] Combustion takes place entirely indoors and is monitored by operators in a central control room. Air from the pit and tipping area is used to burn the waste in order to prevent the escape of dust and odors into the surrounding community. Inside the furnace the temperature is kept above 1800º F and waste is moved using Von Roll moving metal grates.

Ferrous and non-ferrous metals found in the ash are removed and recycled and the remaining bottom ash is landfilled in monofills. Monofills have seven feet of rock, three feet of sand, and two polyethylene liners to prevent groundwater contamination. Any water retained from the liner system is used by the plant or sent to a sewage treatment plant.[220]

The plant operates 365 days per year and has 65 full time employees.[221]

What is the level of energy recovery/generation for the plant?

The plant has one turbine on site, and it generates an electric output rating of 66 Megawatt (MW) gross; 58 MW net—8MW of electricity is used onsite to power the facility. The remaining surplus is sold back to the Utility, via the grid, for 7.27 cents per kilowatt-hour (KWh). For a calendar year, the facility produces 407,408 MW hours[222]. This is the equivalent of supplying energy to 35,000 Florida homes.[223]

What pollution control technology does the plant employ?

In the boiler tubes, gases pass through a scrubber where they are mixed with water mist containing lime.[224] As the gases are cooled the lime neutralizes any acids and produces collectable particles. Next, the fabric filters (baghouses) collect all the particles produced in the boiler and scrubber and absorb them.[225] The cleaned gases are then vented through a stack flue that is 200 feet above the ground. There is 24 hour monitoring of emissions from the plant, as well as annual stack testing to make sure that all emissions are within federal and state limits.[226]

How was the facility financed?

The plant originally raised $277 million in 1989, via industrial revenue bonds. A further $75 million was raised in 1993 through tax-free revenue bonds. These funds were used to cover landfill construction costs and landfill acquisition costs. In 2001, an additional $207 million was acquired by a further issuance of tax-free revenue bonds. The plant was also able to raise $58 million via a private investment in 1990[227]. The bonds are backed by corporate guarantees, a service agreement contract between the company and the County. The County agrees to deliver 1,100,000 tons of MSW per year or pay for any waste shortfall (put-or-pay) and by a Pledge of County credit if tipping fees are not sufficient to pay obligations.[228]

What are the different fees associated with the plant?
Broward County established a tipping fee of $84 per ton in 2003, raising it to $86 in 2005. The actual tipping fee received by the WTE facility is $57. The remainder of the fee covers other solid waste facilities within the county[229].

What aided the success of the facility siting?
The County had worked with the city governments previously on large public service projects and had a history of successful programs.[230] As a result, the County had a good relationship with the municipalities and was trusted by the public.[231] Two of the four cities that decided not to participate previously had poor experiences with the county that lead to mistrust.[232]

There was unanimous state level support for the WTE plant.[233] This could have aided public support because the public may perceive state officials as better trained and more qualified to deal with these situations in comparison to the local government.[234] Additionally, there was no turnover in Commissioners during the siting, allowing for political continuity.[235] Finally, because of the recent landfill closure and increasing population and waste stream, there was a perceived need for the plant.[236]

Today, how is the WTE facility involved with the public?
The WTE facility encourages community service and environmental activism. For example, in 1996 facility employees teamed with the National Audubon Society for the 5th year in a row and had a 24-hour "birdathon" to raise money for the Tampa Bay Bird Sanctuaries.[237] Last year they earned more than $7,000, which the company matched.[238]

Does having a WTE facility affect recycling in this community?
The WTE facility has no adverse affect on recycling. Broward County has a very successful recycling program. Over 135,000 tons of recyclables are collected every year.[239] In fact, the Materials Recovery Facility, which takes recyclables from 26 cities in the county, made about $2.8 million dollars in 2005 from selling recycled materials to industries around the world.[240] In 2004, The non-profit orgranization America Recycles recognized the Broward County Board of Commissioners for its recycling programs.[241]

Additional Information:
In 2004, the Broward WTE facility was awarded Star status by the Occupational Safety and Health Administration (OSHA) for worker safety.[242] Only 951 companies out of 6.5 million received this award. It is given to companies that have a 3-year average injury rate below the industry's average as well as safety programs that far exceed OSHA's standards.[243]

Contact Information:
Mary Beth Busutil, Director, Solid Waste Operations
Broward County Waste and RecyclingService
One N. University Drive
Plantation FL 35324
Telephone: 954-765-4202
Web: www.broward.org

Case Study 2: Tynes Bay Incinerator, Bermuda

Location: Tynes Bay, Bermuda
Population Served: 66,193
Facility Type: Mass Burn Combustion
Year Opened: 1994
Contractor: Von Roll Ltd. & E. Pihl and Son A.S.
Garbage per day: 144 t per day
Energy Capacity: 3.8 MW
Original Capital Cost: $70,000,000
Original Capital Cost Tons per Day: $486,111

What factors lead to the decision to build a WTE facility?

In the 1980s, the government of Bermuda reoriented its waste management policies away from landfilling, instead focusing on incineration, recycling and composting.[244] Landfilling had become problematic because of spatial constraints and environmental hazards. Bermuda is 22 square miles in area, but was generating 80,000 tons of waste annually in the late 1980s.[245] Additionally, the existing landfill posed significant environmental risks. Bermuda obtains large amounts of fresh groundwater from a developed limestone aquifer. Threats to this groundwater source include landfill leachates, oil discharges and contamination from agricultural practices.[246] Water is scarce in Bermuda, so drinking water is collected from roof catchments.[247] New policy sought to address these environmental stresses while minimizing new burdens on the environment.

Planning for a WTE facility began in 1988 with the awarding of concessions. Due to public concern, groundbreaking was delayed for three years.[248] After public hearings and environmental impact studies, construction began in 1991, and the facility came online in 1994. The total cost of the project was $70 million.

What were the major public concerns prior to construction?

Local opposition was keenly attuned to the ongoing debate in the late 1980s about dioxin/furan emissions from WTE plants.[249] Bermudans were concerned that incorporating WTE would come at the expense of local air quality. The proposed disposal of ash in marine reclamation projects also troubled local residents. Concerns centered on whether heavy metals and other hazardous materials might leach out of ash blocks deposited in the harbor.[250]

How did the government address these concerns?

The government arranged for public inquiry, called for extensive environmental impact statements and underwrote research.[251] The government's response to public concerns took place on many fronts:

- *Public hearings.* The initial public hearings occurred in the first quarter of 1988, and the final hearings took place in the first quarter of 1990.[252] The public had the opportunity to give feedback and comments on both the preliminary and final applications of plant design from private contractors. Ultimately, the hearings and further study spurred by public resistance delayed construction for three years.[253]
- *Research.* Research programs were initiated to determine the effect of air emissions and the possibility of effects from leachate from cement blocks on marine life at disposal sites.[254] Scientific study compared three alternatives for ash disposal and concluded that placing them in surrounding bays was the most environmentally sound option.[255]

- *New waste collection program*. The waste stream collection process was altered to remove more toxic waste before incineration.[256]
- *New technical process for concrete.* A new process was developed where cement and ash were mixed to make blocks for marine reclamation works.
- *New criteria for marine disposal.* Bermuda had no guidelines for defining acceptable environmental impact on marine life at disposal sites. Guidelines were develop based on modified US EPA water quality criteria for salt water.[257]
- *Additional facility monitoring and testing.* As part of the original plan to build the plant, the government contracted the Bermuda Institute of Ocean Sciences (formerly the Bermuda Biological Station for Research) to monitor local air quality and assist in developing standards for ambient concentrations of pollutants and fine particulate matter.[258]
-

The combined efforts of the government, the public, contractors and consultants resulted in a workable solution for Bermuda. It is an example of incineration offering a viable solution for islands. One researcher concluded: "sustainable development for small island communities requires innovative solutions which are not necessarily applicable to large industrial nations."[259]

What are the technical specifications of the plant?

Tynes Bay Facility Specifications[260]

Incineration System	Von Roll R-Grate
Incineration Capacity	6 tonnes/hour
Boiler System	Von Roll Horizontal System
Thermal Capacity	2 x 16.3 MW
Electrical Power Capacity	1 x 3,800 KW
Steam Capacity	2 x 17.5 t/h 45 bar 400°C
Condensing Capacity	2 x 18.5 t/h
Sea Water Pumping Capacity	3 x 1000 m^3/h
Flue Gas Cleaning System	2 Electrostatic Precipitators 30 mg/Nm^3 at 11% O_2
Bottom Ash	Drag Chain Conveyor
Fly Ash	Direct Discharge to Quench Tank
Treatment	Ash Concrete Blocks for Land Reclamation

The plant has two lines, each of which can process 6 ton per hour of waste. The plant runs one line fulltime while the second is retained as back-up during outages and scheduled maintenance. The facility operates non-stop for 4000 hours (24 weeks) then is shut down for scheduled maintenance. Steam boilers produce steam at 400°C, which powers a turbine attached to a generator. The steam is cooled with seawater pumped in from the bay.

What is the level of energy recovery/generation for the plant?

Electricity production totals 3.8 MW, almost 5% of the average energy used on the island.

What Pollution Control Technology Does the Facility Employ?

Electrostatic precipitators remove 99% of particulate matter in the flue gas. The remainder is emitted at a height of 75m above the island, ensuring atmospheric dispersion. The Tynes Bay location was chosen, in part, to take advantage of prevailing southwesterly winds that would disperse emissions over the ocean, and not the island.[261] The plant has also installed continuous emissions monitoring systems. Plant emissions are monitored for temperature, carbon monoxide, sulfur dioxide, and hydrogen chloride content. Additionally, the facility's wastewater is collected and absorbed by the hot ash in order to regulate its moisture content.[262]

How Does the Facility Dispose of Ash?
Magnets separate ferrous metals from the residual ash. Ash is mixed with concrete and made into blocks 1 cubic meter in volume that are used for shore protection and land reclamation in Castle Harbor.[263]

Case Study 3: COVANTA Honolulu Resource Recovery Venture

Location: Kapolei, Hawaii
Population Served: 850,000
Facility Type: Refuse Derived Fuel
Year Opened: 1990
Contractor: Covanta Energy
Garbage per day: 2160 tons per day
Energy Capacity: 57 MW
Original Capital Cost: $181,000,000
Original Capital Cost Tons per Day: $83,796

What factors lead to the decision to build a Waste-to-Energy (WTE) facility?
In the 1980s, the city of Honolulu began to consider WTE as a solution to its waste disposal problems.[264] The city was facing pollution and contamination problems related to the illegal dumping of garbage around the island, especially in swampland and ocean areas[265]. In addition, the amount of space available for landfilling decreased throughout the 1980s[266]. The decision to incorporate WTE was motivated primarily by the desire to alleviate pressure on landfills on Oahu."[267] By 1987 the city had settled on building the first WTE facility on the island.[268] The facility, which uses refused-derived-fuel (RDF) waste processing, was completed in 1990 at a cost of $181 million.[269 270]

What were the major public concerns prior to construction?
During the planning phases of the project, key public concerns related to the financial viability and the health risks associated with ash residue from incineration at the proposed plant.[271] These concerns delayed groundbreaking for a few years as the recently elected mayor chose to drop the project.[272]

How did the government address these concerns?
Securing EPA approval for the project and adding environmental controls such as scrubbers to the plant design were crucial to building public support for the project.[273] Both helped to allay fears about health risks from WTE emissions.

Additionally, the public was beginning to understand the limited options available for waste disposal on the island. Support for WTE came in part from public recognition for the volume of waste generated and the desire to take personal responsibility to reduce the amount of trash produced.[274] The spatial impracticality of continued landfilling and the high cost of exporting waste led the public to recognize that WTE was the only sound alternative.[275] Informal and formal community meetings and information sessions helped raise public awareness about these issues. There was also a growing awareness of the need to reduce municipal waste through recycling. As a result the first recycling programs were implemented in the city in 1989.[276]

What are the technical specifications of the plant?
The plant has two boilers, each of which is capable of processing 854 tons of waste per day. Both boilers run constantly, except during outages and maintenance.[277] Waste, including recyclable metals, is presorted, mixed and shredded in two waste processing lines.[278]

Technical Specifications[279]

Location	Campbell Industries Park, Kapolei, Hawaii
Incineration Capacity	2 x 35.6 tons/hour
Boiler System	900 psig/830°F superheater outlet conditions
Electrical Power Capacity	1 x 57 MW

Flue Gas Cleaning System	"Semi-dry flue gas scrubbers injecting lime, fabric filter baghouses, five-field Electrostatic Precipitators and continuous emissions monitoring systems (CEMS).[280]

What is the level of energy recovery/generation for the plant?
The facility has the capacity to generate up to 57 MW of electricity, enough to power about 45,000 homes on Oahu.[281] The plant draws on this energy for its internal needs and sells the excess to the Hawaiian Electric Company.

What Pollution Control Technology Does the Facility Employ?
State-of-the-art air pollution control equipment combined with continuous emissions monitoring systems ensure that emissions remain within state and federal limits.[282] Control technology limits the release of heavy metals, NO_x and SO_2 in emissions. Additionally, third party contractors regularly test and inspect pollution controls.[283] The plant has won environmental safety awards from the American Society of Safety Engineers.[284]

How Does the Facility Dispose of Ash?
Ash is trucked to a landfill for disposal.[285] Recent studies have favorably reviewed the potential for mixing ash with asphalt in road construction projects.[286][287] Analysis of the ash reveals the levels of heavy metals and dioxins to be well within the EPA's toxicological limits.[288]

How was the facility financed?
The cost for building the plant was $181 million, which can be adjusted to $266,877,868 in 2004 dollars. In other words, the original capital cost by design capacity is $83,796 per ton per day, and the adjusted value is $123,555 per ton per day.[289]

What are the different fees associated with the plant?
The tipping for the plant is $55 per ton.[290]

How is the WTE facility involved with the public?
Today, Covanta continues to work with the community to build a mutually beneficial relationship. Below are several examples of how the plant has engaged the communities it serves:

Community Groups and Events[291]

- Involved in local organizations like the Kapolei Rotary Club
- Helps sponsor the Kapolei Family Fun Run to benefit literacy programs and the Waianae Comprehensive Health Care Fun Run
- Involved in the Hawaii Food Bank's food drive.
- Supports the Partnership for the Environment's educational programs promoting recycling on Oahu

Support for Local School Programs[292]

- Sponsors statewide science fairs and school career days. The plant also provides funding for travel expenses of the science fair winners to compete at the district and national levels
- Provides the popular "Science Screen" programs for the Leeward School District. These videos, brochures and teacher guides are aimed at middle and high school levels, providing teachers with modern science education curriculum for use in the classroom.
- As a sponsor of "Project Graduation," the plant supports Leeward High School graduating seniors and their alcohol-free graduation parties
- Covanta also supports youth activities such as an annual varsity girl's softball tournamentat a local high school and the Halau Hula Olana's participation in the International Children's Festival in Washington, DC

Contributions to the Local Economy[293]

- The plant employs 150 people on Oahu.[294] It annually generates a payroll of $10 million dollars, which provides economic stability to the island. Furthermore, $6.5 million dollars are spent annually on equipment and supplies purchased from local vendors, which boosts the local economy.[295]

Does having a WTE facility affect recycling in this community?

Support for WTE also came with public recognition of the amount of waste generated and a desire to take personal responsibility to reduce the amount of trash produced.[296] There was a growing awareness of the need to reduce municipal waste through recycling. As a result, the first recycling programs were implemented in the city in 1989.[297] The current mayor of Honolulu is proposing considerable expansion of the city's recycling program to cope with increasing waste streams.[298]

APPENDIX A. INTRODUCING WASTE INVENTORY MECHANISMS[299]

Waste inventory is an important aspect of a successful waste management plan. By understanding the composition of the waste stream, local officials can make informed decisions regarding waste management budgeting, designing WTE facilities, buying new equipment and estimating space and personnel needs. A waste inventory can also be used to provide accurate estimates of energy generation from a WTE facility. Further, this data can be used to measure whether waste management goals have been meet and whether recycling programs are successful. Waste inventories can be compared across communities to evaluate which strategies work the best.

There are two key aspects of a waste inventory. First is the total amount of waste created and second is the composition of that waste.

Total Waste Tonnage

In order to find the total tonnage of waste produced, WTE facilities and landfills should use a scale to weigh all MSW when it arrives at the facility. If facilities do not have a scale, MSW can be measured by counting the number of trucks that go to the landfill or WTE facility on a given day and multiplying this by the amount of waste each truck on average can hold. This method is less time consuming, but is also less accurate. In addition, all recyclables should be weighed when they arrive at local recycling facilities. MSW per person can be found by dividing the total tonnage of MSW by the population. The recycling rate can be found by dividing the total recycling tonnage by total MSW tonnage. The recycling tonnage per person can be found by dividing the total recycling tonnage by the population.

Total Waste Composition

The composition of the waste stream can be estimated using one of the three sampling methods described below.

1) Quartering Technique: One truck or a group of trucks should unload a previously agreed upon amount of MSW onto a clean surface at the waste disposal facility. The waste should then be mixed with a front-end loader truck and raked into quarters. These steps should be repeated until approximately 200 pounds of MSW is amassed on the surface. Once this happens the waste should be separated into categories and weighed. If examining the MSW composition for a whole community, it is important to use a random sample of trucks from different neighborhoods.

2) Block Technique: This technique should be used when mixing the MSW is difficult to do. This requires laying one truckload or a group of truckloads of MSW on a clean surface, but not mixing it. Instead a sampling team should choose what it feels is a representative sample of the load. The sample is then separated into waste categories and weighed. This technique depends highly on whether the sampling team can pick a representative sample and may not be as accurate as the first method.

3) Grid Technique: This technique requires creating equal size squares on a clean surface. Each square should be given a number. Truckloads of waste should be unloaded on the floor and mixed. This should be repeated until each square holds the same quantity of waste. The waste from a previously chosen number of randomly selected squares should be separated and weighed.

Whatever method is chosen should provide a representative sample of the waste composition. Each community in Puerto Rico should repeat one of the above 3 sampling methods at least 4 times a year in order to account for seasonal variation in the waste stream. If it is not possible for each community to do the above sampling they can estimate their waste composition by using data from a neighboring community. The national government should then collect community information to create a national waste inventory.

APPENDIX B. MODEL EXPLANATION

The following project model was constructed in order to estimate the bottom-up WTE tipping cost for Puerto Rico, under different assumptions. It is useful to any stakeholder who wishes to model the feasibility of WTE project in Puerto Rico.

The following list presents the definition of terms as used in the model:

Plant Size - Puerto Rico produces 11,100 tons of MSW per day. Construction of a WTE facility in Puerto Rico that has a capacity of 2,500 tons per day (tpd) would account for 22.5% of current daily MSW production.

Daily Capacity – The daily capacity is the amount of garbage per day (in tons) that the WTE facility can combust, at 100% of capacity. There are 19 plants in the US that have a daily capacity of 2000 tons or greater. The average daily tonnage capacity for these 19 plants is 2,532 tons per day.[300] A capacity of 2,500 tpd was chosen for the proposed Puerto Rico WTE plant.

Cost per Daily Cost – This represents the capital cost of plant and equipment in dollars where total capital cost is divided by days per year and then by tons per day. WTE facilities are large, expensive facilities, with economies of scale available according to plant size. For the two traditional and widespread combustion options, mass burn and RDF, based on the existing stock of 88 US WTE plants, plant and equipment capital cost, normalized to 2004 dollars, including cost of technology upgrades to comply with tough environmental standards, per ton of daily capacity[301] is estimated to be:

Average cost of all WTE facilities:	$138,000
Average cost of Mass Burn facilities:	$151,000
Average cost of RDF facilities:	$106,000

Puerto Rico produces 11,100 tons of MSW per day. Construction of a WTE facility in Puerto Rico that has a capacity of 2,500 tpd would account for 22.5% of daily MSW production.

Modeling for Puerto Rico's location, there may be some additional an added cost to ship this plant and equipment hardware from the continental United States. Therefore, we added conservative $20,000 per ton of capacity premium to the US average, and when forecasting capital costs for this facility. Therefore, we assume that the cost per daily ton of a large plant will be approximately $170,000 per daily ton.

Daily Capacity – The daily capacity is the amount of garbage per day (in tons) that the WTE facility can combust, when using 100% of its available resources. There are 19 plants in the continental USA and Hawaii that have a daily capacity of 2000 tons or greater, and the average daily capacity for these 19 plants is 2,532 tons per day.[302] Therefore, a capacity of 2,500 tpd was chosen for the proposed Puerto Rico WTE plant. The two dominant expenses for WTE are operations & maintenance and debt service. The two dominant revenue items for WTE are tipping fees and energy sale. The table below shows the magnitude of these 4 items on a per ton basis by region of the U.S:

TABLE 9 - 4. 2003 Average O&M Costs, Debt Service Costs and Energy Revenues Per Ton per Region

Region	O&M	Debt Service	Energy Revenues	Fee Per Ton
All Plants	$50.08	$34.45	$35.16	$49.37
Northeast	$52.21	$34.99	$40.00	$47.20
South	$39.85	$32.95	$20.79	$52.01
Midwest	$69.86	$47.35	$15.93	$101.28
West	$49.82	$32.84	$37.40	$45.26

Land – This figure represents the land that will need to be purchased for the siting and construction of the WTE facility. We use 10 acres.

TABLE 9 - 4. 2003 Average O&M Costs, Debt Service Costs and Energy Revenues Per Ton per Region

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Northeast	$52.21	$34.99	$40.00	$47.20
South	$39.85	$32.95	$20.79	$52.01
Midwest	$69.86	$47.35	$15.93	$101.28
West	$49.82	$32.84	$37.40	$45.26

Land Price – This represents the cost, in dollars per acre, of land in Puerto Rico. The land price multiplied by the land (in acres) yields the capital outlay necessary for land purchase when building the WTE facility.[303]

Days – This is the conservative number of days in a calendar year that the WTE facility is open and running, and makes a 20 day provision for maintenance down-time, reducing days of operation to 345 days per year. We modeled for a 10 acre plot at $200,000 per acre, to yield a capital cost for land at $1 million. Therefore, the net total capital expenditure is forecast to be $426 million.

Ash - This is a figure (in percent) that represents the amount of ash by weight that remains after the waste combustion process. On average in the US, plants produce 28% of their waste tonnage as ash.[304] The revenues stream that would offset the costs associated with the building of the WTE is comprised of both funds generated from the resale of energy, as well as funds generated from tipping fees and the resale of non-ferrous and ferrous metals.

Ash to landfill – This is the amount of ash (in percent) that is landfilled after the waste combustion process. In some jurisdictions there are markets into which this material can be sold. 20 US plants are currently making beneficial use of ash, reselling it for general construction or landfill cover.[305] We assume zero.

Ash Sales Price – This is the resale value of the ash that remains, post combustion. We assume zero on the basis that a materials market may not exist in Puerto Rico.

Landfill Tipping Fee – This is the cost, in dollars per ton, to support the existing landfill dumping process. Inclusive in the tipping fee is payment for MSW transport. The rate assumed for disposal of ash from a WTE plant is $40, a slight increase over the average $37 cost in Puerto Rico.

WTE Tipping Fee – This is the cost, in dollars per ton, that can be charged by the WTE facility to receive MSW.

Operator Fee – This is the all-in fee that the operator of the facility will charge for the services undertaken at the facility. It is represented here as a percentage of the WTE tipping fee. We assume a 6% margin based on general data from

Locality Fee - This is a fee that the locality may levy for allowing local siting of the facility. It is represented by a certain percentage of the WTE tipping fee.

Personnel – This is the amount of people, represented as full time equivalents (FTEs),that are employees of the WTE facility. In the US at 500 tons, there are about 37 employees, and for every ton thereafter, about 2.2 employees are necessary.[306] Therefore we use 80 employees.

Cost Per Person – This is the salary attributed to every of FTE employees at the WTE facility. The cost per person, multiplied by the personnel number yields the dollar amount spent on labor at the WTE facility for a year.

Maintenance – This represents the cost of maintenance for the plant and equipment at the WTE facility. It is represented in percent per year of original Capital Costs, and yields a dollar figure when multiplied by the plant and equipment construction cost. It is conservatively based on US plant average.

Insurance - This represents the cost to insure the plant and equipment at the WTE facility. It is represented in percent per year of original Capital Costs, and yields a dollar figure when multiplied by the plant and equipment construction cost. It is conservatively based on US plant average.

Electricity production net – This figure represents an electricity rating, for how much electricity, in kilowatt hours, is net generated for every ton of trash combusted at the WTE facility. The kWh/t produced for the 19 plants with a daily capacity over 2,000 tpd is 553.[307] We use 560 kWh/tons for our model under the conservative assumption that it will purchase an efficient new generator.

Electricity price – This is the price, in cents per kilowatt hour, that the WTE facility will receive when selling its electricity generation back to the grid and to the Puerto Rico Electric Power Authority (PREPA). We use 80% in the conservative case and 90% in the realistic case, of the retail price of Puerto Rico under the assumption that Puerto Rican WTE project can negotiate favorably with PREPA.

Electricity Internal Use – This is the amount of energy, in percentage basis, that the WTE facility uses from its own electricity generation to power the plant daily operations. The remaining electricity generated can be sold back to PREPA and the grid. Of the 19 large US plants, the average gross electric output rating is 65.3 MW.[308] WTE facilities can run off the energy that that they generate. The remaining energy that can be sold to the grid is represented as a net electric output rating. The average net electric output rating for these 19 plants is 52 MW net.[309] The difference between the gross and net electric output rating is internal use and is 20% on average.[310] The average internal use over these 19 plants is 20%. We will use this as a proxy for the modeling of the proposed WTE plant in PR.

Electricity REPI – It is a federal monetary incentive, measured in cents per kilowatt-hour (kWh), that the WTE could gains through sale of electricity generated from a renewable source. It is set at zero in the conservative case because it is contingent upon federal continuing appropriation. It is set at $0.018/kWh in the realistic case.

Electricity PTC – It is a monetary incentive, measured in cents per kWh, that the WTE gains through sale of electricity generated from a renewable source, in this case, the WTE facility itself. It is $0.0075/kWh.

Ferrous % in Ash – This is the amount of ferrous metals recoverable from the ash, post combustion. This number is represented by percent of ash. In the US, metals total 18.7% of MSW, of which 36.8% are recovered, meaning 6.88% of MSW weight is recovered metals total.[311] We conservatively assume 5% total metals recovery: 4.75% ferrous and 0.25% non-ferrous.

Ferrous price/ton – This represents the dollar amount per ton of ferrous metal in the resale market.

Non-Ferrous % in Ash – This is the amount of non-ferrous metals recoverable from the ash, post combustion. This number is represented by percent of ash.

Non-Ferrous price/ton – This represents the dollar amount per ton of non-ferrous metal in the resale market.

Borrowing Rate – This is the interest rate payable on a loan taken on by a credit worthy party like the owners of the WTE facility. It is conservatively estimated at 0.75% over Puerto Rico's 2006 long-term borrowing rate.

Project Return Rate – This is the projected rate of return on investment for the WTE facility. 15% is a standard assumption.

Tax Rate – This is the rate, in percent, at which total taxable profit is taxed. 35% is used.

Borrowing Term – This is the duration of the loan that is taken out to finance the building of the WTE facility. We assume 30 years and that the loan will be amortized on a straight-line basis over 30 years.

Debt – This number represents the proportion of the project that is financed by debt (via taking out loans). We assume 75%.

Equity – This number represents the proportion of the project that is financed by equity holders. These equity holders have purchased a stake in the ownership of the WTE facility in proportion to the amount of capital that they committed to the project. We assume 25%.

Using the assumptions from above, the "conservative case" is summarized below:

MODEL: CONSERVATIVE CASE
ASSUMPTIONS

Plant Size / Daily Tons	2,500	tons	Electricity production net	560	kWh/t
Cost per Daily Cost	$170,000	per ton	Electricity price	$0.052	per kWh
Land	10	acres	Electricity Internal Use	20%	
Land Price	$150,000	per acre	Electricity REPI	$0.000	per kWh
Days	345	per yr	Electricity PTC	$0.0075	per kWh
Ash	28%	per ton	Ferrous % in ash	4.75%	per ton
Ash to landfill	100.0%	per ton	Ferrous price/ton	$100	per ton
Ash sales price	$0	per ton	Non Ferrous % in ash	0.25%	per ton
Landfill tipping fee	$45	per ton	Non Ferrous price/ton	$2,000	per ton
WTE tipping fee	$62	per ton	Borrowing Rate	5.75%	per yr
Operator Fee	6.0%	of tipping	Project Return Rate	15%	per yr
Locality Fee	4.0%	of tipping	Tax Rate	35%	per yr
Personnel	80	fte	Borrowing Term	30	years
Cost Per Person	$50,000	per yr	Debt	75%	
Maintenance	2.0%	per yr	Equity	25%	
Insurance	1.0%	per yr			

MODEL: CONSERVATIVE CASE
PRIMARY OUTPUTS

Electricity Production	386,400	MWh/y
NPV FCF	$10,328,507	million
IRR	16.6%	

MODEL: CONSERVATIVE CASE
SECONDARY OUTPUTS

CAPITAL COST (FIXED)	**YEAR 1**
Plant & equipment construction	$425,000,000
Land Purchase	$1,500,000
Total Capital	$426,500,000
REVENUE (VARIABLE)	
Tipping fees	$53,475,000
Energy sale	$20,092,800
Metals Sale	$2,354,625
Ash Sale	$0
Renewable Energy Incentive or Credit	$2,898,000
Total Revenue	$78,820,425
OPERATIONAL & CAPITAL COSTS (V & F)	
Labor	$4,000,000
Plant Maintenance	$8,500,000
Insurance	$4,265,000
Operator Fee	$3,208,500
Ash Disposal	$10,867,499
Locality Fee	$2,139,000
Total Expense	$32,979,999
Earnings Before Interest, Tax, Depreciation	$45,840,426
Interest	$18,392,813
Depreciation	$14,166,667
Total Taxable Profit	$13,280,947
Tax	$4,648,331
Production Tax Credit	$2,898,000
Net Income	$11,530,615
Free Cash Flow	$18,571,738
Per Ton Operating	$38
Per Ton Debt Service (Interest + Amortization)	$26
Per Ton Operating & Debt Service	$64
Per Ton Energy	$23
Per Ton Materials	$3
Per Ton WTE Tipping	$62
Per Ton Revenue	$88
Per Ton Net Income	$13

The "realistic case" varies only from the conservative case in terms of changed assumptions for Electricity price and Electricity REPI.

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